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TITLE OF THE INVENTION

**METHOD AND SYSTEM FOR
AUTOMATICALLY LOCATING END OF TRAIN DEVICES**

BACKGROUND OF THE INVENTION

5 **Field of the Invention**

The invention relates generally to railroad end of train units, and more particularly to an improved method for keeping track of end of train units.

Discussion of the Background

10 Within the railroad industry, end of train (EOT) units are typically attached at the rear of the last car on a train. As is well known in the art, these EOT units can perform one or more of a variety of functions. EOT units monitor air pressure in the air brake pipe and transmit this information to the head of the train (HOT). EOT units also often include an end-of-train marker light. Two-way EOT units can accept a command from the HOT to open the air brake pipe (loss of air pressure in
15 the air brake pipe causes the brakes to activate and stop the train) in an emergency situation. Some EOT units include motion detectors that are used to inform the HOT as to whether, and in some cases in which direction, a train is moving. Other EOT units include GPS receivers that are used to transmit location information pertaining to the end of the train to HOT equipment as discussed in U.S. Patent No.
20 6,081,769. EOT units usually communicate with the HOT using radio-based communications.

Supplying power to EOT units is an important consideration. As discussed in U.S. Patent Nos. 5,267,473 and 6,236,185, it is known to supply power to EOT

units using batteries or a combination of batteries and air-powered generators connected to the brake pipe. In order to conserve battery power, EOT units are usually configured to power down when the unit is tipped over from a vertical orientation to a horizontal orientation by trainyard personnel when the EOT is not
5 in use.

As their name implies, EOT units are mounted at the end of a train. Because various cars in trains are often shuffled in and out of consists and because trains are often reformed during operation, it is often necessary to install and remove EOT units from individual cars in a train yard. Because EOT units are
10 often heavy and/or bulky, EOT units removed from cars are often left by the wayside for collection at a later time. Unfortunately, EOT units left by the wayside in this manner often become misplaced or “lost.” Thousands of wayside units are lost this way each year. Even a temporarily misplaced EOT unit can cost a railroad money. For example, rent must be paid for the time when an EOT unit from one
15 railroad is in another railroad’s territory. Thus, if such an EOT unit is temporarily misplaced, the rent is increased.

What is needed is an apparatus and method for tracking EOT units.

BRIEF SUMMARY OF THE INVENTION

The present invention meets the aforementioned need to a great extent by
20 providing an end of train unit that includes a positioning system such as a GPS receiver and that is configured to transmit a message including the EOT unit’s location when the EOT unit detects a loss of air pipe pressure, a low battery condition, or when the EOT unit is tipped over or in response to a query from a

device located off the train. The EOT unit may communicate directly with a device located off the train. Alternatively, an EOT unit-generated message intended to be received by a device located off the train may be transmitted by the EOT unit to the HOT and re-transmitted by the HOT to the device located off the train.

5 In highly preferred embodiments, the EOT unit periodically re-transmits the message until an acknowledgment message is received. In such embodiments, the HOT may be configured to detect a situation in which an EOT unit has ceased re-transmitting the message before an acknowledgment message is received, and when such a situation is detected, to begin transmitting a message including the
10 EOT position (which message may be a substantial duplicate of the message transmitted by the EOT unit) until an acknowledgment is detected.

 In another aspect of the invention, messages containing EOT unit locations are collected by an EOT unit monitoring station. The EOT unit monitoring station generates a message including the EOT location information and routes the
15 message to appropriate personnel responsible for tracking the EOT units. The EOT unit monitoring station preferably translates the positioning system coordinates from the EOT unit into another set of coordinates (e.g., milepost locations) and/or generates a display in which the EOT unit location is superimposed over a map to aid a human being in locating the device. Preferably, the message from the EOT
20 unit monitoring station to the personnel is repeated until an acknowledgment of the message and/or a confirmation that the EOT unit has been retrieved is received from the personnel.

 In some embodiments of the invention, the EOT unit and a device located at the HOT communicate with each other using low power radio communications

which cannot travel long distances, but the HOT is also equipped with a long range communication system (e.g., a high power rf or satellite transceiver) that is capable of communicating with devices (e.g., a dispatcher transceiver) located a great distance off the train. In such embodiments, a message including an
5 identification number of a particular EOT unit that is "lost" or whose location is to be determined for any other reason may be sent to one or more (or all) HOT devices via the long range communication system. The HOT devices in turn transmit a query message directed to the lost device via the low power communication system and relay any message received from the lost EOT unit on
10 the low power communication system via the long range communication system. This allows any EOT unit within the range of the short range communications system to be located even if the EOT unit is not connected to any HOT.

In yet another aspect of the invention, information from the positioning system is used to create a signal as a substitute for a motion sensor. In still another
15 aspect, position information from the positioning system is used to determine the speed of the end of the train.

BRIEF DESCRIPTION OF THE DRAWINGS

A more complete appreciation of the invention and many of the attendant features and advantages thereof will be readily obtained as the same become better
20 understood by reference to the following detailed description when considered in connection with the accompanying drawings, wherein:

Figure 1 is a block diagram of an end of train unit according to one embodiment of the invention.

Figure 2 is a flow chart illustrating a location reporting subroutine performed by the end of train unit of Figure 1.

Figure 3 is a flow chart illustrating operation of a motion sensing subroutine performed by the end of train unit of Figure 1.

5 Figure 4 is a block diagram of a system including an end of train unit according to a further embodiment of the invention.

Figure 5 is a message sequence diagram illustrating a flow of messages between components of the system of Figure 4 according to another embodiment of the invention.

10 Figure 6 is a flowchart illustrating the processing performed by one of the head of train units of Figure 4 according to yet another embodiment of the invention.

DETAILED DESCRIPTION

The present invention will be discussed with reference to preferred
15 embodiments of end of train units. Specific details, such as types of positioning systems and power supply subsystems, are set forth in order to provide a thorough understanding of the present invention. The preferred embodiments discussed herein should not be understood to limit the invention. Furthermore, for ease of understanding, certain method steps are delineated as separate steps; however,
20 these steps should not be construed as necessarily distinct nor order dependent in their performance.

An end of train unit 100 according to one embodiment of the invention is illustrated in Fig. 1. The EOT unit 100 includes a processor 110. The processor

110 may be a microprocessor or may be implemented using discrete components.

The processor 110 is responsible for implementing the logical operations discussed in detail below.

5 The processor 110 receives electrical power from a power supply subsystem 120. The power supply subsystem 120 is substantially the same as that described in U.S. Patent No. 6,236,185, the contents of which are hereby incorporated herein by reference. The power supply subsystem 120 includes an air-powered electrical generator 122 connected to an air brake pipe 10. The output of the generator 122 is connected to a rectifier 124. The output of the rectifier 124 is connected to a
10 voltage regulator 126 whose output is connected to continuously recharge a rechargeable battery 128 and to supply power to the processor 110. In this manner, if air pressure is lost in the air brake pipe 10, the processor 110 will continue to receive power from the battery 128. It should be noted that a battery alone, an air-powered generator alone, or other types of power subsystems such as those
15 disclosed in U.S. Patent No. 5,267,473, could be used in place of the power subsystem 120 of Fig. 1.

A positioning system 130 is also connected to the processor 110. The positioning system 130 is a GPS receiver in preferred embodiments. The GPS receiver can be of any type, including a differential GPS, or DGPS, receiver. Other
20 types of positioning systems 130, such as inertial navigation systems (INSs), Loran systems, and wheel tachometers, can also be used. Such positioning systems are well known in the art and will not be discussed in further detail herein. [As used herein, the term "positioning system" refers to the portion of a positioning system that is commonly located on a mobile vehicle, which may or may not comprise the

entire system. Thus, for example, in connection with a global positioning system, the term “positioning system” as used herein refers to a GPS receiver and does not include the satellites that are used to transmit information to the GPS receiver.]

As discussed above, conventional EOT units include a motion detector that
5 allows HOT equipment to detect when the end of the train is in motion. One of the intended uses is to allow the HOT to determine when the end of the train has become uncoupled from the head of the train. In some embodiments of the invention, the positioning system 130 is used in place of a motion detector. In such
10 embodiments, if the positioning system 130 only provides position information, the processor 110 (or other equipment at the HOT) can compare successive positions from the positioning system 130, taking into account known errors in the positioning system 130, to determine whether the end of train is in motion. In
15 embodiments with positioning systems that provide speed information, motion can be detected by monitoring the speed information received from the positioning system 130, again taking into account known errors in the positioning system 130. In some embodiments, a threshold of 1 m.p.h. is used to determine whether or not the train is in motion.

An air pressure transducer 140 is also connected to the processor 110. The air pressure transducer is connected to monitor the air pressure in the air brake pipe 10
20 (this connection is not shown in Fig. 1). The air pressure information from the transducer 140 is supplied to the HOT in a conventional fashion. As discussed further below, the processor 110 also interprets a loss of air pressure in the air brake pipe 10 and/or an indication that the EOT unit 110 has been tipped over as an indication that the EOT unit is to go out of service and that it may be necessary to

begin transmitting the EOT unit's location to an EOT unit monitoring station (not shown in Fig. 1).

As discussed above, conventional EOT units are mounted on the end of the train such that they may be tipped over from a vertical position to a horizontal position when not in service. Preferred embodiments of the invention follow this convention and include a tilt sensor 150 connected to the processor 110. The tilt sensor 150 detects when the EOT unit 100 has been tipped over, such as when the EOT unit 100 has been removed from a car and laid on its side. The processor 110 uses the information from the tilt sensor 150 and/or brake pipe air pressure information from the air pressure transducer 140 to determine when to begin transmitting EOT location information. Although a tilt sensor 150 is used in preferred embodiments, any other device or mechanism, such as a simple on/off switch, can be used in place of the tilt sensor 150 to indicate that the EOT unit is to go out of service.

A transceiver 160 connected to the processor 110 allows for two-way communications between the EOT unit 100 and HOT equipment. Among other things, the transceiver 160 transmits air brake pipe pressure information to HOT equipment and, in some embodiments, receives commands to open the air brake pipe 10 for braking operations from the HOT equipment. In embodiments in which the positioning system 130 replaces a motion detector and in which motion detection processing is performed by the processor 110, the transceiver 160 is also capable of transmitting a message from the processor 110 to the head of the train when the end of the train has begun and/or stopped moving. Additionally, the transceiver 160 is preferably capable of transmitting a message including location

information to an EOT unit monitoring station (not shown in Fig. 1) when the processor 110 determines that the EOT unit 100 is to go out of service as will be discussed more fully below or in response to a query from the EOT unit monitoring station which may or may not be associated with a dispatcher. In some
5 embodiments, the transceiver 160 is a short range transceiver such as a two watt radio frequency transceiver. In other embodiments, the transceiver 160 may be suited for long range communications (e.g., a 100 watt radio frequency or satellite transceiver) that may be of the same type used by an HOT device to communicate with a central authority such as a dispatcher.

10 A flowchart 200 illustrating a monitoring subroutine performed by the EOT unit 100 is shown in Fig. 2. This monitoring subroutine may be called at a periodic rate, such as once a second. In embodiments of the invention that do not include a power subsystem 120 with a battery 128 but rather are powered solely by an air powered generator, the periodic rate is chosen to ensure that the processor 110 will
15 have sufficient time to transmit at least one location message before power from the air powered generator is lost as a result of a loss of air pressure in the air brake pipe 10. It should be understood that the monitoring subroutine illustrated in the flowchart 200 is only one function performed by the EOT unit 100. Other
20 functions, such as reporting the pressure in the air brake pipe 10, turning marker lights on and off, and responding to braking commands, are also performed in separate subroutines in a conventional manner. These other subroutines will not be discussed in further detail herein.

The processor 110 obtains the air pressure in the air brake pipe 10 from the air pressure transducer 140 at step 202. If the brake pipe pressure is acceptable at step

204, the processor 110 determines whether the battery 128 voltage is acceptable at step 205. In preferred embodiments, the processor 110 includes a built-in A/D converter connected to the battery 128 for this purpose. Alternatively, an external A/D converter (not shown) could be provided for monitoring the battery voltage. If the voltage is acceptable at step 206, the processor 110 queries the tilt sensor 150 at step 206. If the tilt sensor 150 indicates that the EOT unit 100 has not been tipped over at step 208, the subroutine ends.

If the brake pipe pressure is not acceptable at step 204 or if the battery voltage is low at step 205 or if the EOT unit 100 has been tipped over at step 208, the processor 110 obtains the current location of the EOT unit 100 from the positioning system 130 at step 210. The processor 110 then transmits the current location to an EOT tracking station (not shown in Fig. 1) via the transceiver 160 at step 212. If an acknowledgment of the current location message is not received at step 214, the processor 110 delays for a period of time and then re-transmits the current location message at step 212. The subroutine 200 ends when an acknowledgment of the current location message is received at step 214 or when power to the EOT unit 100 is lost.

In the subroutine 200 described above, the processor 110 begins transmitting a location message when either the brake pipe 10 pressure is lost or the battery voltage is low or the EOT unit 100 is tipped over. In other embodiments of the invention, the processor 110 does not begin transmitting the location information until all three conditions are present concurrently or until two or more conditions are present concurrently (e.g., both the brake pipe pressure is lost and the EOT unit 100 is tipped over).

In the embodiment described above, the location message from the end of train unit 100 includes position information from the positioning system, such as latitude and longitude. This information may be translated into a position related to the railroad, such as track number and/or position on the track relative to a landmark such as a milepost, by equipment at the EOT monitoring station. In alternative embodiments, the processor 110 may perform this conversion.

Those of skill in the art will recognize that implementation as a polled subroutine is but one way in which to implement the reporting function described above in connection with the flowchart 200. Any number of other implementations, such as implementation as an interrupt service routine triggered by an interrupt generated by a loss of brake pipe air pressure indication from the transducer 140 and/or a tilt indication from the tilt sensor 150.

The EOT unit 100 is also configured to respond to a query message from an end-of-train unit monitoring station in some embodiments. Such a message might be transmitted at any time, not just when the EOT unit is to go out of service. This feature can be used by the end-of-train unit monitoring station, which may be (but is not necessarily) associated with a dispatcher to keep track of trains in train yards as well as to locate EOT units.

In some embodiments of the invention, the EOT unit 100 also includes a motion sensor (not shown in Fig. 1), and information from the motion sensor is transmitted to the HOT so that the HOT can determine whether or not the train is in motion. Other embodiments of the invention do not include a motion sensor. In such embodiments, the processor 110 uses information from the positioning system 130 to determine motion (or lack thereof) of the end of the train and transmits this

information to the HOT via transceiver 160. An example of a subroutine, callable at a periodic rate, that implements this function according to one embodiment of the invention is illustrated by the flowchart 300 of Figure 3.

5 The processor 110 obtains the current position of the EOT unit 100 from the positioning system 130 at step 302 and compares this position to the previous position at step 304. The difference between the current and previous positions is compared to a threshold at step 306. The threshold is preferably chosen to take inaccuracies associated with the positioning system into account. If the difference between the current and previous positions is greater than the threshold at step 306,
10 the processor 110 sends a message to the HOT indicating that the train is in motion at step 308. Otherwise, the processor 110 sends a message to the HOT indicating that the train is not in motion at step 310. It should also be noted that these messages may also be sent to an entity off the train, such as a dispatcher. Next, the processor saves the current position as the previous position at step 312 and the
15 subroutine ends.

The subroutine 300 is but one simple manner of implementing a process for using a positioning system 130 in place of a motion sensor. Other, more sophisticated embodiments are also within the scope of the present invention. For example, rather than simply calculating a difference between the current and
20 previous positions, successive differences could be filtered using any variety of known techniques, e.g., Kalman filtering. In other embodiments of the invention, the processor 110 reports not only a simple motion/not in motion indication, but also provides speed information to the HOT and/or an entity not onboard the train, such as a dispatcher. In some of these embodiments, the speed is supplied directly

by the positioning system 130; in other embodiments, the speed is calculated by the processor 110 based on filtered successive location reports from the positioning system 130. It should also be noted that the processor 110 may also be configured to turn an EOT marker light on and off based on whether the information from the positioning system indicates that the train is in motion.

The EOT unit 100 discussed above is suitable for use in a wide variety of systems. An exemplary system 400 with which the EOT unit 100 may be used is illustrated in Figure 4. The system 400 includes a plurality of trains 405, each including an EOT unit 400 and an HOT unit 415. The EOT units 400 include EOT processors 410 and short range communications systems 460, which may comprise short range radio frequency transceivers in some embodiments. Additional components of the EOT units 400, such as the power supply and the positioning system, are not illustrated in Figure 4 for the sake of clarity. Also shown in Figure 4 is a lost EOT unit 400a, which is not connected to any train.

The HOT units 415 include an HOT processor 416, a short range communications system 417 suitable for communications with the short range communications systems 460 on the EOT units 400, and a long range communications system 418. The long range communications systems 418 may be, for example, a high power RF or satellite transceiver.

Also forming part of the system 400 is a central authority 420, which may perform the role of the EOT unit monitoring station discussed above in some embodiments of the invention. The central authority 420 includes a processor 422, a long range communication system 426 suitable for communicating with the long

range communications systems 418 in the HOT devices 415, and a land-based communication system 424.

5 The land-based communication system 424 is connected to a local EOT monitoring station 430, which includes a communication system compatible with the short range communications systems 460 of the EOT units 400. A first EOT personnel device 440 is also connected to the land-based communications system. A second EOT personnel device 450, which may take the form of a mobile, hand-held device in some embodiments of the invention, includes a communications system compatible with the long range communications system 426 of the central
10 authority 420.

The central authority 420 is responsible for both keeping track of end of train units 400 and, more importantly, for ensuring that end of train units 400 are properly collected and/or transported by the appropriate EOT personnel. An exemplary message sequence diagram 500 illustrating message traffic in one
15 possible transaction is illustrated in Figure 5.

The transaction begins with the central authority 420 transmitting a location query message 502 including the identification number of a desired EOT unit via the long range communication system 426 (preferably, each of the EOT units 400 is assigned a unique identification number). When the central authority 420 has
20 reason to believe that the EOT unit 400 of interest is coupled to a particular HOT unit 415, the message 502 may be addressed to that particular HOT unit (which also preferably have unique identification numbers). Alternatively, the message 502 may be broadcast to all HOT units 415 in the system 400. The HOT unit(s) 415 transmits a location query message 504, again including the EOT unit

identification number, via the short range communication system 417. The EOT unit with the identification number in the message 504 responds by transmitting an EOT location message 506, which preferably (but not necessarily) includes the EOT unit's identification number via the short range communication system 460.

5 The HOT unit 415 receives this message 506 via the short range communication system 417 and transmits a message 508 with the EOT location information (again, preferably including the EOT unit identification number) to the central authority via the long range communication system 418. The central authority preferably responds to the message 508 by sending an acknowledgment message 510 to the

10 HOT unit 415, which then transmits an acknowledgment message 512 to the EOT unit 400.

It should be understood that the EOT unit 400 in the foregoing transaction may be an EOT unit attached to a train 405, or may be an EOT unit 400a not connected to any train. This may occur, for example, when the central authority broadcasts an

15 EOT location message to all HOT units 415 in an attempt to locate an EOT device 400 which happens to be within communications range of an HOT device 415. It should be further understood that transaction illustrated in Figure 5 may also begin with the transmission of an EOT location message 506 rather than with a query 502 from the central authority 420. This may occur, for example, when an EOT unit

20 detects a condition (e.g., a tilt or a loss of brake pipe pressure) indicating that it is to go out of service and transmits its location in response to this condition.

Once the central authority 420 has successfully located the EOT unit 400 of interest, the central authority 420 ensures that the EOT unit 400 is properly attended to by the responsible EOT personnel. This may involve, for example,

collecting an EOT unit 400 that has been taken off a train and laid by the wayside.

The central authority 420 begins this task by transmitting an EOT location message

514 to an EOT personnel device 440, 450. The message 514 may be directed

toward an EOT personnel device 440 at a fixed location via the land-based

5 communications system 424, or may be directed toward a mobile EOT personnel device 450 via the long range communications system 426 (or possibly even a third communications system). It is also possible for the central authority to broadcast the message 514 to all EOT personnel devices in the system, which is particularly useful when the system includes mobile devices 450. The EOT location

10 information in the message 514 may be in the form of the EOT location as provided by the positioning system in the EOT unit 400, or may be translated by the central authority 420 into a different form, such as a set of map coordinates or milepost markers. In response to the message 514, the EOT personnel device 440, 450 transmits an acknowledgment message 516 to the central authority 420. This
15 message may be automatically generated by the EOT personnel device 440, 450 in response to the message 514, but is more preferably generated in response to an action by a human being indicating that this person has been appraised of the location of the EOT unit 400.

Once the EOT personnel device 440, 450 receives the EOT location message
20 514, the EOT personnel device 440, 450 preferably displays the location on a map image to facilitate location of the device by the appropriate personnel. The map image may be stored locally on the device 440, 450. Displaying the EOT unit's location on the map may require the translation of the location information from the message 514 into a different form for use with the map image. Alternatively,

the central authority 420 may have preformed any necessary translation as discussed above.

In some embodiments, the central authority's job is complete once the acknowledgment message 516 is received from the EOT personnel device 440, 450. However, in other embodiments, the central authority 420 also ensures that the EOT unit 400 is properly collected. In such embodiments, the central authority 420 transmits a query 518 and repeats the transmission until a confirmation message 520 indicating that the EOT unit 400 has been attended to is received from the EOT personnel device 440, 450.

Other variations on the transaction illustrated in Figure 5 are also possible. For example, a trainyard may be equipped with a single local EOT monitoring station 430, which may perform the tasks of locating the EOT unit 400 and notifying EOT personnel devices 440, 450 discussed above in connection with the central authority 420. In such embodiments, the local EOT monitoring stations 430 may communicate directly with the EOT units 400 using a short range communication system as shown in Figure 4. Alternatively, the local EOT monitoring station 430 may communicate with the EOT units 400 via a long range communication system in the same manner as the central authority 420.

In yet other embodiments, a trainyard may be equipped with a plurality of local EOT unit monitoring stations 430 which may be used by a central authority with responsibility for a limited area such as a trainyard for communications with EOT units 400 rather than communicating with the EOT units 400 via the HOTs using the long range communications system 426. Still other arrangements and combinations are possible.

In some embodiments of the invention, the HOT units 415 are configured to act as “repeaters” that continue broadcasting an EOT unit location message if no acknowledgment of the message is detected by the HOT unit 415. This may occur when the EOT unit 400 has detected an out-of-service condition but has depleted
5 its back-up battery power before its location information message was transmitted or received.

Figure 6 is a flowchart 600 illustrating the processing performed by such an HOT unit 415 in this aspect of the invention. The process starts with the HOT unit 415 monitoring messages sent by the EOT unit 400 at step 602. If the HOT unit
10 415 receives a message from the EOT unit 400 that is not a location message being sent by upon the detection of an out of service condition at step 604, the HOT unit 415 continues to monitor the EOT unit messages at step 602. If, however, the message from the EOT unit 400 is an out-of-service message at step 604, the HOT unit 415 waits a predetermined period for an acknowledgment message from some
15 other device (e.g., the central authority 420 or a local EOT unit monitoring station 430) at step 605. The message from the EOT unit 400 may explicitly indicate an out of service condition. Alternatively, the HOT unit 415 may infer that the message from the EOT unit is an out of service condition because the message was unsolicited.

20 If the HOT unit 415 detects an acknowledgment message at step 606, the process ends. If no acknowledgment message is detected at step 606, the HOT unit 415 then determines whether the EOT unit 400 has transmitted another location message at step 608 (in such embodiments, the EOT units 400 may be configured to continue transmitting the location messages until an acknowledgment is

received). If the EOT unit 400 has transmitted another message, step 608 is repeated. If no acknowledgment message is detected by the HOT unit 415 at step 608, the HOT unit 415 re-transmits the EOT unit location information at step 610 until an acknowledgment is detected at step 612, at which point the process ends.

5 The message transmitted by the HOT unit 415 at step 610 may be a duplicate of the message transmitted by the EOT unit 400, which includes the EOT unit's identification number/address, thereby appearing to a recipient to have been transmitted by the EOT unit 400. Alternatively, the message transmitted by the HOT unit 415 at step 610 may include the EOT unit's identification number but
10 may further include information identifying the HOT unit 415 as the source of the message.

It should be noted that the various embodiments of the invention discussed herein vary in significant respects with the system described in U.S. Patent No. 6,505,104, which provides a rudimentary EOT unit tracking function. That system
15 is primarily concerned with monitoring HOT-EOT communications and is significantly different in that respect. Additionally, the '104 patent system does not include EOT units that include positioning systems, or EOT units that recognize out of service conditions and begin transmitting location information messages in response thereto. Still further, that system does not provide the ability to query
20 EOT units as to their location. Rather, the system of the '104 patent employs a plurality of wayside monitoring stations at known positions that simply monitor messages including EOT unit ID's that are periodically transmitted by the EOT units. The information from each of the wayside monitoring stations is then

collected and cross referenced with the locations of the monitoring stations to track the EOT monitoring units as they pass by the various wayside monitoring stations.

While the invention has been described with respect to certain specific embodiments, it will be appreciated that many modifications and changes may be made by those skilled in the art without departing from the spirit of the invention. It is intended therefore, by the appended claims to cover all such modifications and changes as fall within the true spirit and scope of the invention.

WHAT IS CLAIMED IS:

1. An end of train unit comprising:
 - a processor;
 - a transmitter connected to the processor; and
 - 5 a positioning system connected to the processor;wherein the processor is configured to perform the steps of
 - detecting a condition indicating that the end of train unit is to go out of
 - service;
 - obtaining location information from the positioning system; and
 - 10 transmitting a message including the location information upon
 - occurrence of the condition.
2. The end of train unit of Claim 1, further comprising a receiver connected to the processor, wherein the processor is further configured to repeat the transmitting step if a response to the message is not received.
- 15 3. The end of train unit of Claim 1, further comprising a tilt sensor connected to the processor, wherein the condition is an indication from the tilt sensor that the end of train unit has been tilted.
4. The end of train unit of Claim 1, further comprising a transducer connected to the processor and configured to measure air pressure in an air brake pipe of the
- 20 train, wherein the condition is an indication from the transducer that air pressure in the air brake pipe is below a threshold.
5. The end of train unit of Claim 1, wherein the condition is an indication from an analog-to-digital converter configured to measure a voltage of a battery connected to supply power to the processor that the voltage is below a threshold.

6. The end of train unit of Claim 1, further comprising:

a transducer connected to the processor and configured to measure air pressure in an air brake pipe of the train; and

a tilt sensor connected to the processor;

5 wherein the condition is either an indication from the transducer that air pressure in the air brake pipe is below a threshold or an indication from the tilt sensor that the end of train unit has been tilted.

7. The end of train unit of Claim 1, further comprising:

a transducer connected to the processor and configured to measure air pressure
10 in an air brake pipe of the train; and

a tilt sensor connected to the processor;

wherein the condition comprises concurrent indications from the transducer and the tilt sensor that air pressure in the air brake pipe is below a threshold and that the end of train unit has been tilted.

15 8. The end of train unit of Claim 1, wherein the processor is further configured to perform the steps of:

obtaining a plurality of positions from the positioning system; and

transmitting a message indicating whether or not the train is in motion based on the plurality positions from the positioning system.

20 9. The end of train unit of Claim 1, wherein the message including the location information is transmitted to a head of the train.

10. The end of train unit of Claim 1, wherein the message including the location information is transmitted to a device off the train.

11. The end of train unit of Claim 1, wherein the message including the location information is transmitted to a device off the train via a device at the head of the train.

12. The end of train unit of Claim 11, wherein the message is transmitted to
5 the device at the head of the train with the transmitter and the message is transmitted from the head of the train to the device off the train using a communication system of a type different from a type of the transmitter.

13. The end of train unit of Claim 1, wherein the processor is further configured to perform the steps of:
10 obtaining a plurality of positions from the positioning system;
calculating a speed of the train based on the plurality of positions from the positioning system; and
transmitting a message indicating the speed.

14. A method for facilitating the location of an end of train unit comprising
15 the steps of:
detecting a condition indicating that the end of train unit is to go out of service;
obtaining location information from the positioning system; and
transmitting a message including the location information upon
20 occurrence of the condition to a device off the train.

15. The method of Claim 14, further comprising the step of repeating the transmitting step if a response to the message is not received.

16. The method of Claim 14, wherein the condition is an indication that the end of train unit has been tilted.

17. The method of Claim 14, wherein the condition is an indication that a battery voltage is below a threshold.

18. The method of Claim 14, wherein the condition is an indication that an air pressure in an air brake pipe of the train is below a threshold.

5 19. The method of Claim 14, wherein the condition is either an indication that air pressure in an air brake pipe on the train is below a threshold or an indication that the end of train unit has been tilted.

20. The method of Claim 14, wherein the condition comprises an indication that a battery voltage is below a threshold and an indication that the end of train
10 unit has been tilted and an indication that an air pressure in an air brake pipe of the train is below a threshold.

21. The method of Claim 14, wherein the condition comprises concurrent indications that an air pressure in an air brake pipe of the train is below a threshold and that the end of train unit has been tilted.

15 22. The method of Claim 14, further comprising the steps of:
obtaining a plurality of positions of the train from a positioning system; and
transmitting a message indicating whether or not the train is in motion based
on the plurality of positions.

23. The method of Claim 22, wherein the message is transmitted to a head of
20 the train.

24. The method of Claim 22, wherein the message is transmitted to a device off the train.

25. The method of Claim 14, further comprising the steps of:
obtaining a plurality of positions from the positioning system;
calculating a speed of the train based on the plurality of positions; and
transmitting a message indicating the speed.

5 26. The method of Claim 25, wherein the message is transmitted to a head of
the train.

27. The method of Claim 26, wherein the message is transmitted to a device
off the train.

28. A method for facilitating the tracking of an end of train unit comprising
10 the steps of:

monitoring a pressure in an air brake pipe of a train on which the end of train
unit is mounted;

obtaining a position of the end of train unit from a positioning system; and
transmitting the position to a device located off the train when the pressure

15 falls below a threshold.

29. A method for facilitating the tracking of an end of train unit comprising
the steps of:

detecting when the end of train unit has been tilted;

obtaining a position of the end of train unit from a positioning system; and

20 transmitting the position to a device located off the train when the end of train
unit has been tilted.

30. A method for determining when an end of train is in motion comprising
the steps of:

providing a positioning system on the end of the train;

obtaining a plurality of positions from the positioning system;
determining whether the train is in motion based on the plurality of positions;
and
transmitting a message indicating whether the train is in motion based on a
5 result of the determining step.

31. A method for determining a speed of an end a train comprising the steps
of:

providing a positioning system on the end of the train;
obtaining a plurality of positions from the positioning system;
10 determining a speed of the train based on the plurality of positions; and
transmitting a message including the speed.

32. A method for facilitating the locating of an end of train unit comprising
the steps of:

receiving a message originating from a source located off the train at the end
15 of train unit; and

transmitting a location of the end of train unit in response to the message.

33. The method of Claim 32, wherein the end of train unit comprises a global
positioning system receiver and the location is based on information from the
global positioning system receiver.

20 34. The method of Claim 32, wherein the message originating from the source
off the train is received via a device at a head of a train and wherein the location of
the end of train unit is transmitted from the end of train unit to the device at the
head of the train and subsequently transmitted from the device at the head of the
train to the device located off the train.

35. A method for facilitating the locating of an end of train unit comprising the steps of:

detecting at a head of train unit a message sent by an end of train unit, the message including the end of train unit's location; and

5 transmitting the end of train unit's location from the head of train unit if no acknowledgment of the message is detected.

36. The method of Claim 35, wherein the head of train unit only performs the transmitting step if the message is being sent by the end of train unit upon a detection of a condition indicating that the end of train unit is to go out of service.

10 37. The method of Claim 35, wherein the head of train units transmits a message that is a duplicate of the message transmitted by the end of train unit.

38. A method for facilitating collection of end of train units comprising the steps of:

receiving a message including a location of an end of train unit; and

15 transmitting a first message including the location of the end of train unit to an entity responsible for collecting the end of train device.

39. The method of Claim 38, further comprising the step of transmitting a second message if an indication that the end of train device has been collected is not received.

20 40. The method of Claim 39, wherein the second message is transmitted to the same entity as the first message.

41. The method of Claim 39, wherein the second message includes the location of the end of train device.

42. The method of Claim 38, further comprising the step of displaying a map including an indication as to the location of the end of train unit.

43. An end of train unit comprising:

a processor;

5 a transmitter connected to the processor; and

a positioning system connected to the processor;

wherein the processor is configured to perform the steps of

obtaining a plurality of positions from the positioning system;

determining whether the train is in motion based on the plurality of

10 positions; and

transmitting a message indicating whether the train is in motion based on a result of the determining step.

44. The end of train unit of Claim 43, wherein the determining step is performed by obtaining a first position from the positioning system, obtaining a
15 second position from the positioning system, calculating a difference between the first position and the second position, and comparing the distance to a threshold.

45. The end of train unit of Claim 43, wherein the determining step is performed by calculating a speed of the train based on a plurality of positions reported by the positioning system and comparing the speed to a threshold.

20 46. An end of train unit comprising:

a processor;

a transmitter connected to the processor; and

a positioning system connected to the processor;

wherein the processor is configured to perform the steps of

obtaining a plurality of positions from the positioning system;
determining a speed of the train based on the plurality of positions; and
transmitting a message including the speed with the transmitter.

47. An end of train unit comprising:

5

a processor;

a transceiver connected to the processor; and

a positioning system connected to the processor;

wherein the processor is configured to perform the steps of

receiving a message originating from a source located off the train with

10

the transceiver; and

transmitting a location of the end of train unit in response to the

message.

48. The end of train unit of Claim 47, wherein the positioning system is a
global positioning system receiver and the location is based on information from
15 the global positioning system receiver.

49. The end of train unit of Claim 47, wherein the message originating from
the source off the train is received via a device at a head of a train, and wherein the
location of the end of train unit is transmitted from the end of train unit to the
device at the head of the train and subsequently transmitted from the device at the
20 head of the train to the device located off the train.

50. The end of train unit of Claim 49, wherein the message includes an
address of the device located off the train.

51. A head of train unit comprising:

a processor; and

a first transceiver connected to the processor;

wherein the processor is configured to perform the steps of

detecting a message sent by an end of train unit, the message including
the end of train unit's location; and

5 transmitting the end of train unit's location from the head of train unit
if no acknowledgment of the message is detected.

52. The head of train unit of Claim 51, wherein the processor only performs
the transmitting step if the message is being sent by the end of train unit upon a
detection of a condition indicating that the end of train unit is to go out of service.

10 53. The head of train unit of Claim 51, wherein the head of train units
transmits a message that is a duplicate of the message transmitted by the end of
train unit.

54. The head of train unit of Claim 51, further comprising a second
transceiver, wherein the message sent by the end of train unit is received using the
15 first transceiver and the transmitting step is performed using the second
transceiver.

55. The head of train unit of Claim 51, wherein the message sent by the end of
train unit is received using the first transceiver and the transmitting step is
performed using the first transceiver.

20 56. An end of train unit tracking device comprising:

a processor;

a receiver connected to the processor;

a transmitter connected to the processor; and

a memory connected to the processor;

wherein the processor is configured to perform the steps of
receiving a message including a location of an end of train unit; and
transmitting a first message including the location of the end of train
unit to an entity responsible for collecting the end of train device.

5 57. The device of Claim 56, wherein the processor is further configured to
perform step of transmitting a second message upon a failure to receive an
indication that the end of train device has been collected.

58. The device of Claim 57, wherein the second message is transmitted to the
same entity as the first message.

10 59. The device of Claim 57, wherein the second message includes the location
of the end of train device.

60. A device for aiding a person in locating an end of train unit, the device
comprising:

a processor;

15 a database connected to the processor, the database including map data
suitable for displaying a map;

a receiver connected to the processor; and

a display connected to the processor;

wherein the processor is configured to perform the steps of

20 receiving a message including a location of an end of train unit; and
displaying a map including an indication as to the location of the end
of train unit on the display.

61. The device of Claim 60, further comprising a housing, the processor, database, receiver and display being positioned inside the housing, the housing being of a size suitable for hand-held operation.

ABSTRACT

An end of train unit includes a positioning system such as a GPS receiver and is configured to transmit a message including the EOT unit's location when the EOT unit detects a loss of air pipe pressure and/or it is tipped over and/or a low
5 battery condition is detected. In highly preferred embodiments, the EOT unit periodically re-transmits the message until an acknowledgment message is received. In some embodiments, information from the positioning system is used to create a signal as a substitute for a motion sensor. In other embodiments, information from the positioning system is used to determine the speed of the end
10 of the train. End of train unit tracking is also performed.

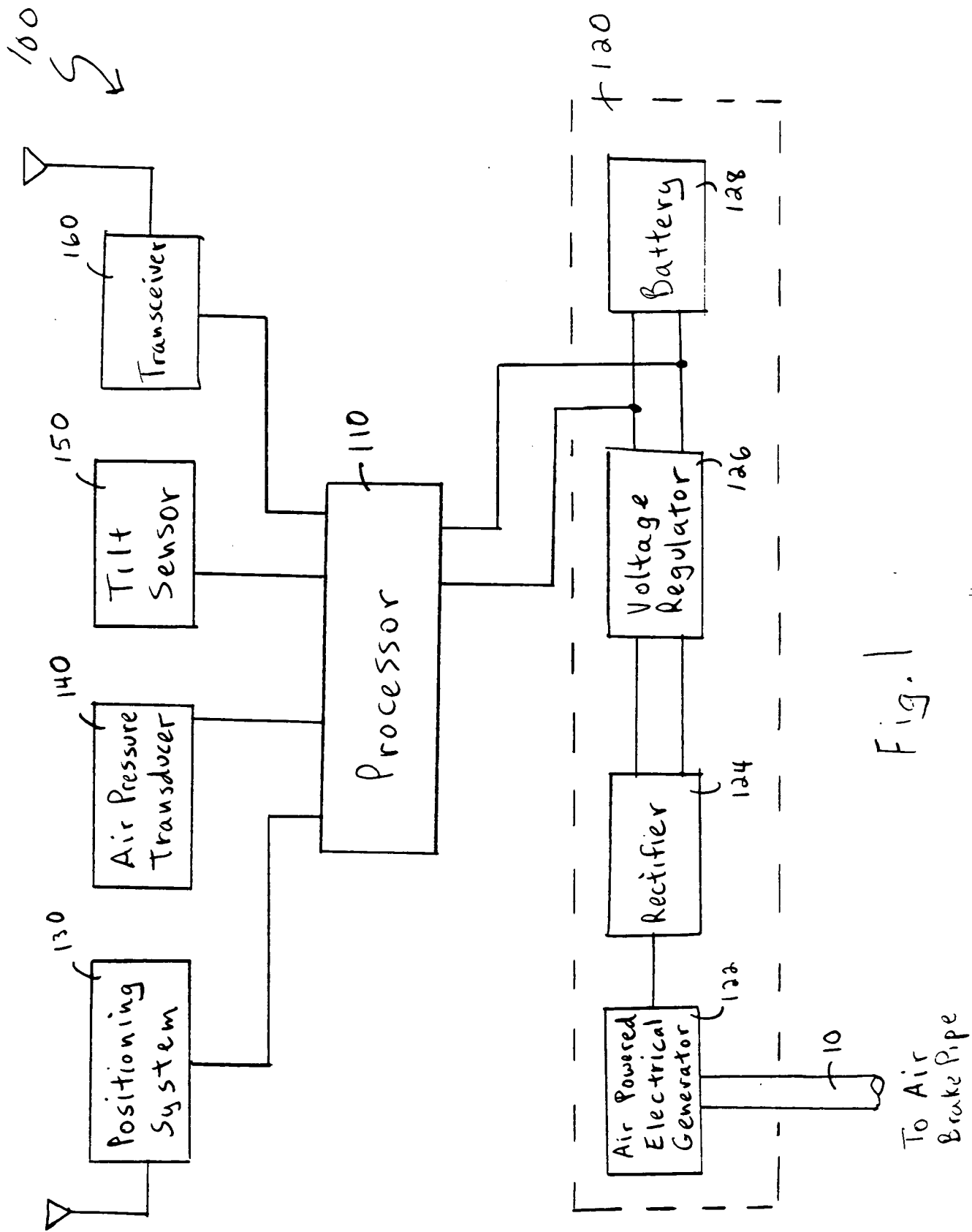


Fig. 1

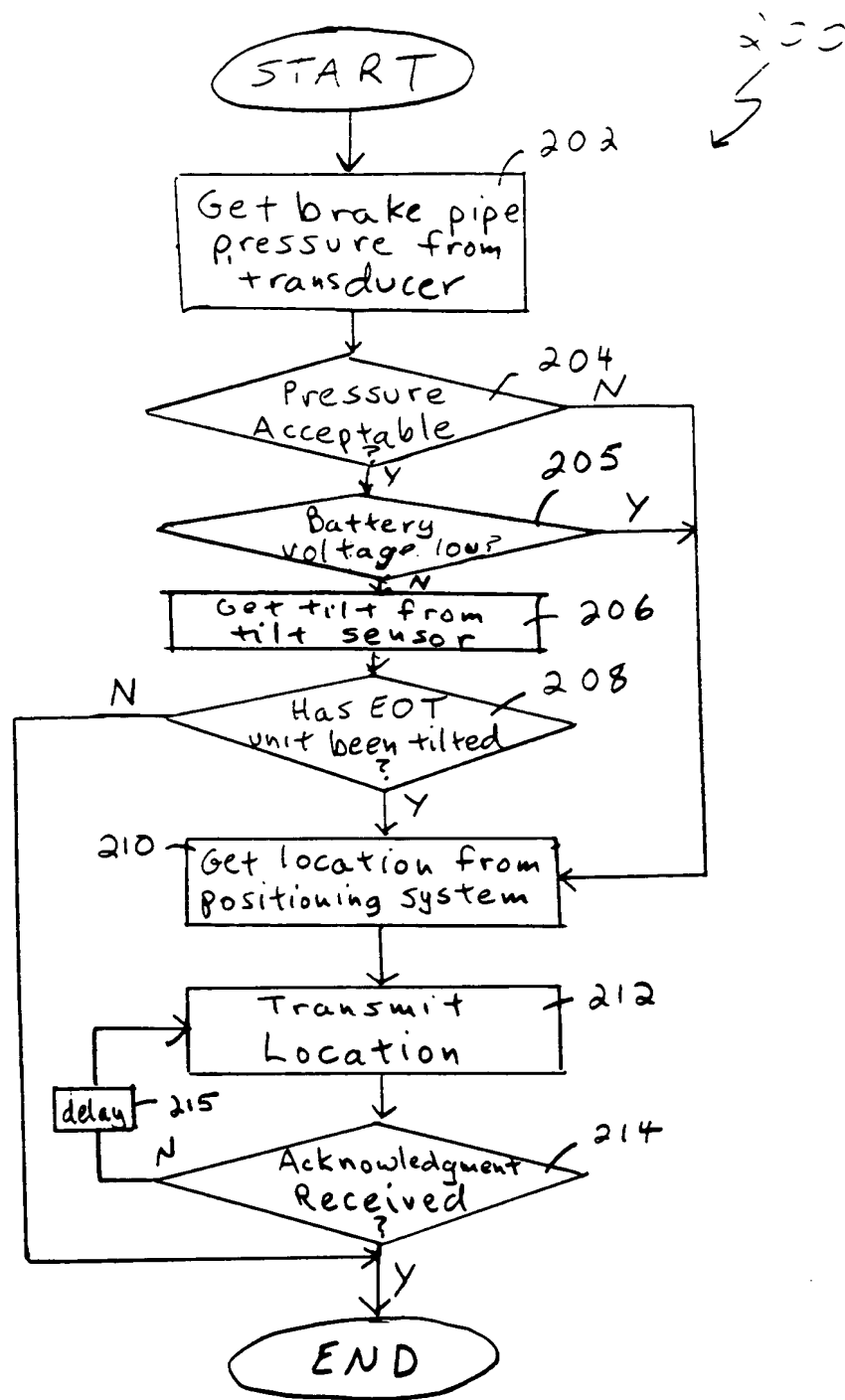


Figure 2

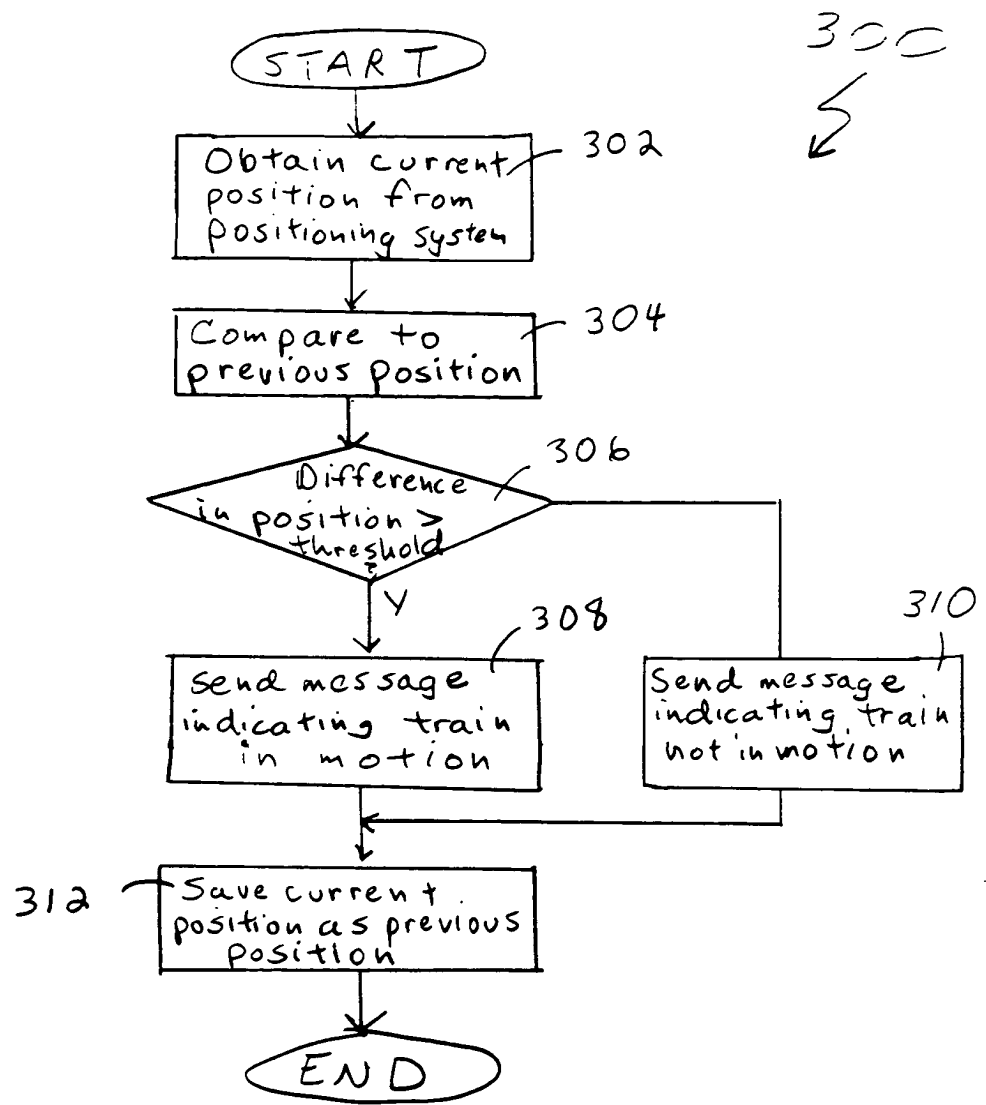


Figure 3

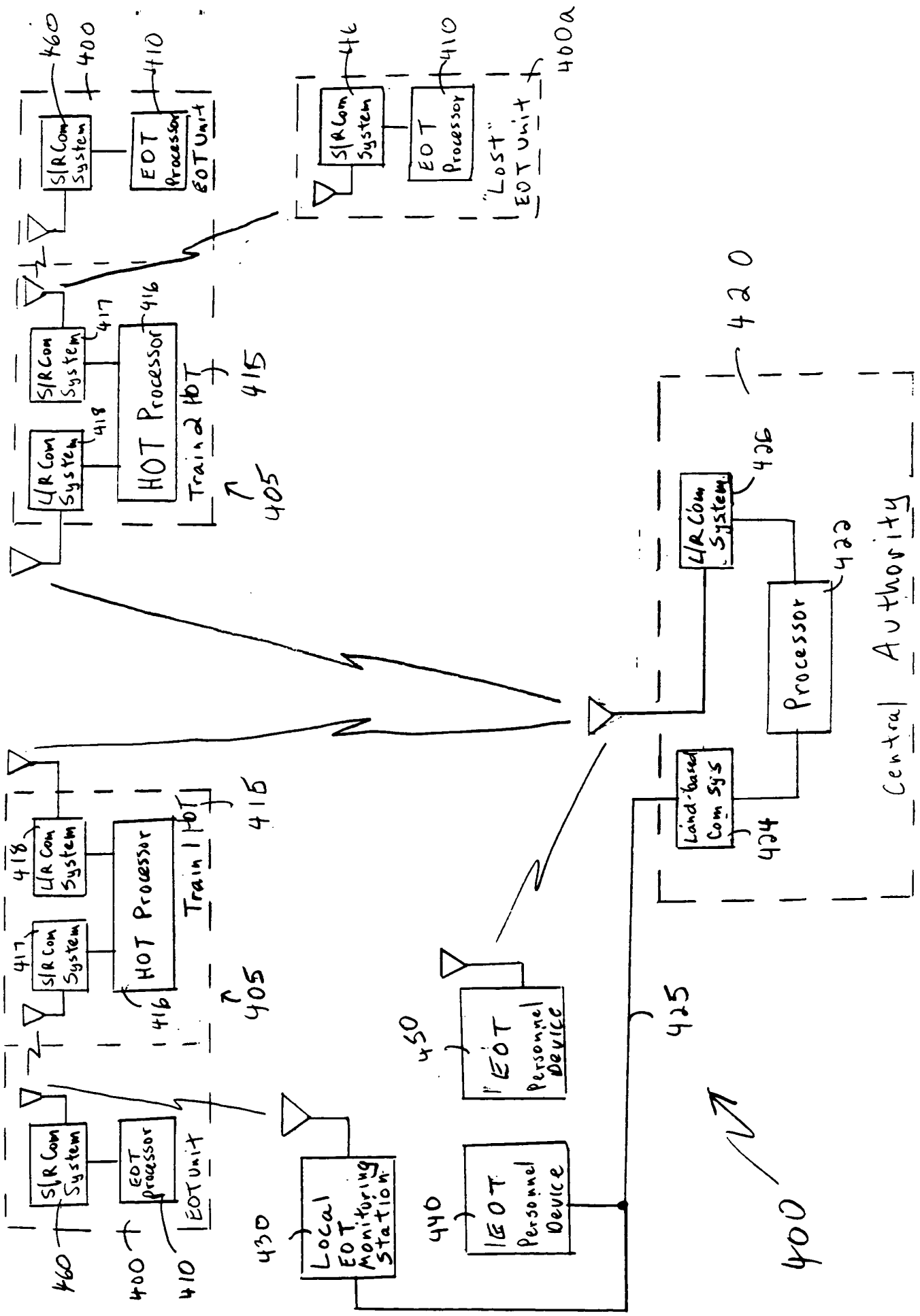


Figure 4

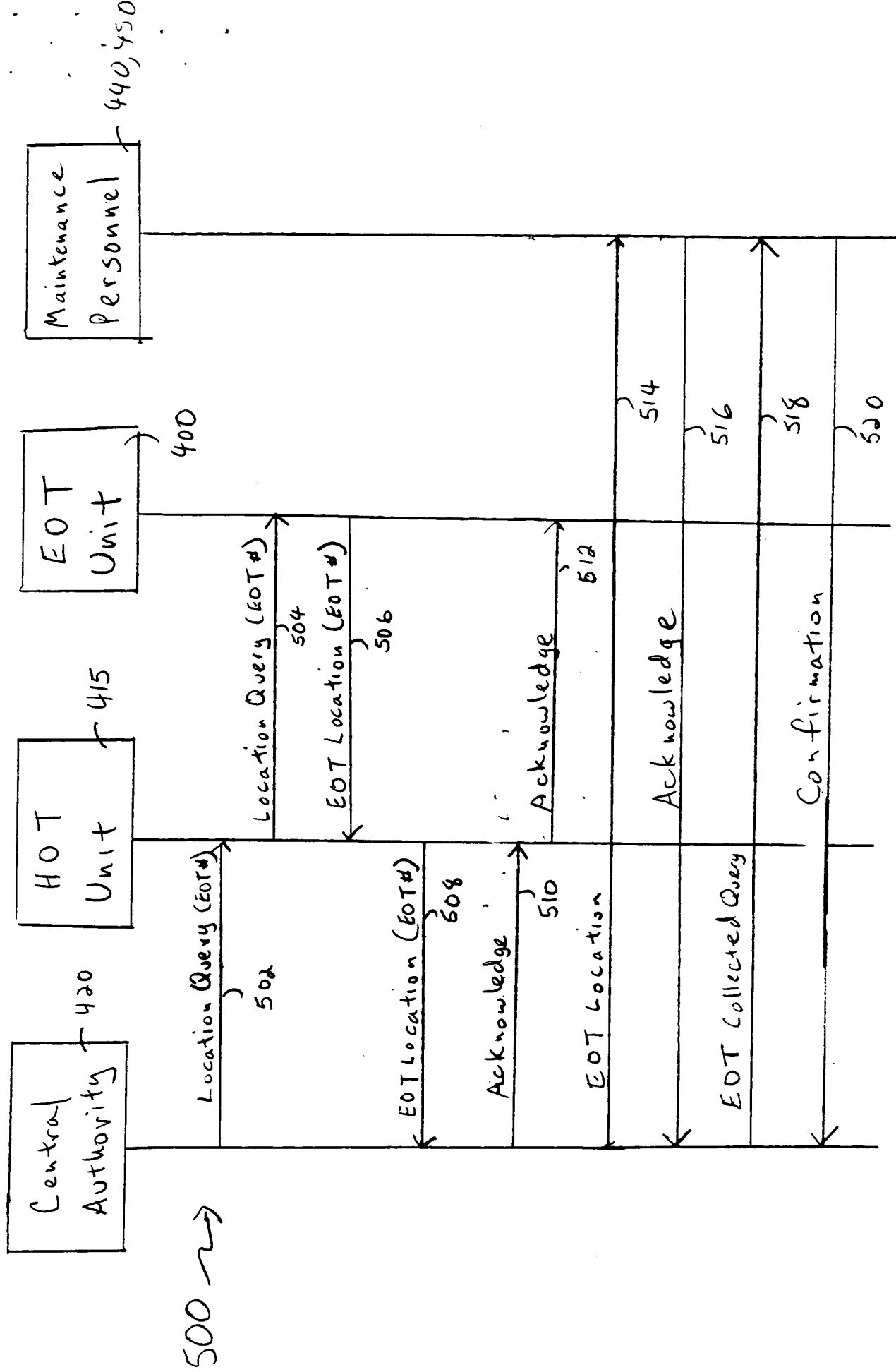


Figure 5

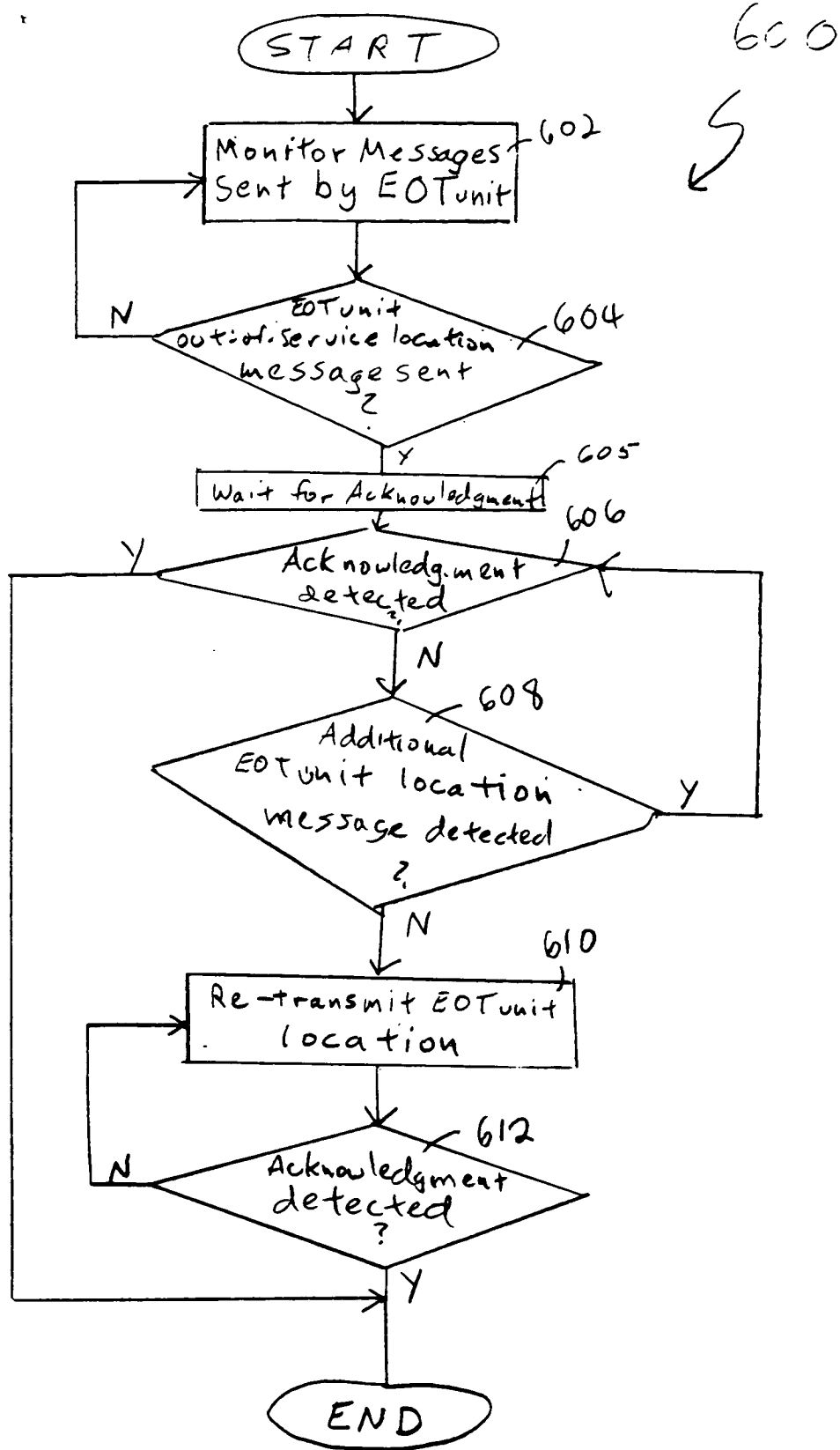


Figure 6

DOCKET NO: 3805-016-27 CIP ✓

TITLE OF THE INVENTION

**METHOD AND SYSTEM FOR
COMPENSATING FOR WHEEL WEAR ON A TRAIN**

This application is a Continuation-In-Part of application Serial No.

5 10/157,874, filed May 31, 2002, the entirety of which is incorporated herein by
reference.

BACKGROUND OF THE INVENTION

Field of the Invention

The invention relates to railroads generally, and more particularly to a
10 system and method for determining wheel size to compensate for wheel wear.

Discussion of the Background

Controlling the movement of trains in a modern environment is a complex
process. Collisions with other trains must be avoided and regulations in areas such
as grade crossings must be complied with. The pressure to increase the
15 performance of rail systems, in terms of speed, reliability and safety, has led to
many proposals to automate various aspects of train operation. For example,
positive train control (PTC) and automatic train control (ATC) systems have been
widely discussed in recent years.

Some automated systems rely on global positioning system (GPS) receivers
20 for indications of train speed and position (as used herein, "global positioning
system" and "GPS" refer to all varieties of global positioning system receivers,

including, but not limited to, differential global positioning system receivers. Still other systems use inertial navigation systems (INSs) for determining speed and location. However, GPS receivers and INSs sometimes fail, and for that reason it is desirable to have a back-up system.

5 One method that can be used in case of a positioning system failure is to measure the rotation of motor, axle or wheel rotation to determine the speed at which a train is traveling and/or the distance which a train has traveled. Each time the wheel makes a complete revolution, the distance traveled by the wheel is equal to its circumference in the absence of any slippage. Thus, if the radius R of the
10 wheel is known, the distance traveled for each revolution of the wheel is equal to $2\pi R$. However, the radius of a wheel changes over time due to wheel wear. For example, a standard train wheel can decrease in size from 40 inches to 36 inches over its useful life. Therefore, the distance traveled in each wheel revolution can vary between 125.7" and 113.1", a difference of approximately 12.6" or 10%. This
15 error is significant.

What is needed is a method and system that compensates for wheel wear.

SUMMARY OF THE INVENTION

The present invention meets the aforementioned need to a great extent by providing a method and system for compensating for wheel wear in which wheel
20 rotation information from a revolution counter or a tachometer and position and/or speed information from an independent positioning system such as GPS or INS are measured over a predetermined distance and used to determine the size of the train wheels. This process is performed periodically to compensate for wheel wear.

In one aspect of the invention, the system includes a map database and the position information from the independent positioning system is used to as an index to ensure that the rotation data used for the speed/position comparison between the position system and rotation data is collected in an area of straight and flat track so as to exclude errors in the rotation data caused by wheel slippage and turns.

In another aspect of the invention, the data used for the comparison between the speeds/distances indicated by the positioning system and by the rotation data is collected over a long distance to minimize known errors in the positioning system. In yet another aspect of the invention, a total distance traveled is calculated using an integration technique by adding a plurality of linear differences in successive positions reported by the positioning system over short periods of time. This technique is particularly advantageous when performed over curved sections of track.

BRIEF DESCRIPTION OF THE DRAWINGS

A more complete appreciation of the invention and many of the attendant features and advantages thereof will be readily obtained as the same become better understood by reference to the following detailed description when considered in connection with the accompanying drawings, wherein:

Figure 1 is a logical block diagram of a train control system according to one embodiment of the invention.

Figure 2 is a flowchart showing a wheel wear compensation technique according to one embodiment of the invention.

Figure 3 is a logical block diagram of a train speed signal distribution system according to another embodiment of the present invention.

Figures 4(a) and 4(b) are, respectively, schematic drawings of distance calculated by a linear method and an integration method according to an
5 embodiment of the present invention.

Figure 5 is a flowchart of a wheel wear compensation technique employing the integration method of Figure 4(b) according to an embodiment of the invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

The present invention will be discussed with reference to preferred
10 embodiments of train control systems. Specific details, such as wheel sizes and types of positioning systems, are set forth in order to provide a thorough understanding of the present invention. The preferred embodiments and specific details discussed herein should not be understood to limit the invention.

Referring now to the drawings, wherein like reference numerals designate
15 identical or corresponding parts throughout the several views, Figure 1 is a logical block diagram of a train control system 100 according to the present invention. The system 100 includes a control module 110, which typically, but not necessarily, includes a microprocessor. The control module 110 is connected to a revolution counter 120. The revolution counter 120 measures rotation of a
20 locomotive wheel (not shown in Fig. 1) on a train. The revolution counter 120 may be of any type, including mechanical, magnetic, and optical. The revolution counter 120 may measure the rotation of a wheel directly, or may measure rotation

of an axle to which the wheel is connected, or may measure rotation of a motor driveshaft or gear that powers the wheel.

Also connected to the control module 110 is a positioning system such as a GPS receiver 130. The GPS 130 receiver can be of any type, including a
5 differential GPS receiver. Other types of positioning systems, such as inertial navigation systems (INSs) and Loran systems, can also be used. [As used herein, the term “positioning system” refers to the portion of a positioning system that is commonly located on a mobile vehicle, which may or may not comprise the entire system. Thus, for example, in connection with a global positioning system, the
10 term “positioning system” as used herein refers to a GPS receiver and does not include the satellites that are used to transmit information to the GPS receiver.] The GPS receiver 130 provides position and speed information to the control module 110.

The control module 110 uses the position information from the GPS
15 receiver 130 as an index into a map database 140. The map database 140 provides information including track grade and curvature to the control module 110. As will be explained in further detail below, this information is used in some embodiments to ensure that rotation information from the revolution counter will not include rotation information that is corrupted due to wheel slippage and/or errors due to
20 track curvature.

Referring now to Fig. 2, a flowchart 200 illustrates operation of a wheel wear correction method according to one embodiment of the present invention. The control module 110 determines whether track conditions are acceptable at step 210. In some embodiments, this is accomplished by obtaining the current position

from the GPS receiver 130 and indexing the map database 140 to determine the track grade and curvature over a predetermined length of upcoming track over which rotation information is to be collected.

5 The predetermined length of track is preferably of a sufficient length such that any errors introduced by the inaccuracy of the global positioning system receiver 130 are minimized. Obviously, it is advantageous to use as great a length as possible since the effect of positioning systems errors are decreased as the length is increased. However, there is a trade-off that must be made because if the length is too great, the time required to complete the wheel correction algorithm is too
10 long and/or the amount of curvature and grade in the track segment over which the data is to be taken preclude running the algorithm over too much track in the system. In some embodiments, the predetermined length of track is 100,000 meters. In such an embodiment, with a global positioning system having a position error on the order of 30 meters, the total error is equal to $(30 + 30)/100,000 = .0006$
15 = .06%.

 In the embodiment described by Fig. 2, the determination as to whether track conditions are acceptable is made at the start of the algorithm. In other embodiments, rotation data is only collected if the train is traveling greater than some minimum. The reason behind this is that most wheel slippage occurs at slow
20 speeds as a locomotive is attempting to accelerate. Most locomotives use electric induction motors, and most electric motors used in locomotives have torque curves with torques decreasing as speed increases such that it is not possible for the locomotive to generate enough torque to cause the wheels to slip above certain

speeds. In some embodiments, the minimum speed at which data will be collected is 15 m.p.h.; in other embodiments, the minimum speed is 20 m.p.h.

In yet other embodiments, the wheel acceleration is monitored to detect wheel slippage. If an acceleration exceeds a threshold, the collected information is
5 discarded and the entire process is started over.

In still other embodiments, the system notes the upcoming sections of the track in which either the grade or curvature is above a corresponding threshold and does not include those distances and any corresponding rotation information collected over those distances in the calculations. Such embodiments are
10 particularly useful for railroads in which long, straight and level sections of track are not present in many areas.

If the track conditions are not favorable at step 210, the system delays for a period of time at step 220 and repeats step 210 until track conditions are favorable. When track conditions are favorable at step 210, the control module 110
15 determines a start position from the global positioning receiver 130 at step 230 and counts rotations as measured by the revolution counter 120 at step 240. When a threshold (which may be a number of rotations and/or a time period) has been reached at step 250, the control module 110 determines a stop position from the global positioning receiver 130 at step 260. Next, at step 270, the control module
20 130 calculates the distance D traveled based on the start and stop positions measured at steps 230 and 260, respectively. Then the control module 130 determines the radius R of the wheel at step 280 according to the equation $R = D/2\pi T_r$, where T_r is the total number of rotations counted over the distance D. The

control module 110 then delays, at step 290, for a period of time such as a day (it is not necessary to run the algorithm often as train wheels wear slowly).

In the above-discussed embodiments, a predetermined distance is used. It should be noted that the predetermined distance will vary depending upon the accuracy of the positioning system used and the particular environment in which the invention is used.

In the foregoing embodiments, data is not collected when the system determines that track conditions are not favorable. However, in cases where curvature exceeds the threshold, it is also possible to allow data collection to occur and correct the data for the curvature.

In another embodiment of the invention, an integration technique is utilized to correct for track curvature. In this technique, the total distance traveled is determined by adding linear differences between positions reported by the positioning system at a plurality of short intervals. In this manner, the sum of linear distances closely approximates the actual "track distance" (the actual distance traveled by the train over the track). Consider the examples shown in Figs. 4(a) and 4(b), which illustrate a section of track 400 between two points A and B. In Fig. 4(a), a linear distance D_0 between points A and B is illustrated. This distance D_0 is obviously less than the actual track distance between points A and B. In Fig. 4(b), several linear distances D_{1-9} between a plurality of intermediate points I_{0-9} are calculated. The sum of these linear distances D_{1-9} is a much closer approximation of the track distance between points A and B. As the distance between the intermediate points I_{0-9} decreases, the approximation of the actual track distance becomes more accurate.

Fig. 5 illustrates a flow chart 500 of the steps performed by the control module 110 in an embodiment employing this integration technique. The revolution counter 120 is reset to zero at step 502 (in other embodiments, the revolution counter is simply read at step 502). The position is then obtained from the positioning system 130 at step 504 and temporarily stored as the last position at step 506. The control module 110 then delays for a period of time at step 508. As discussed above, the shorter the period is, the more accurate the approximation will be. In preferred embodiments, the period is one second.

After the delay at step 508, the control module 110 again obtains the current position at step 510. Next, the linear difference between the current position and the temporarily stored last position is calculated at step 512 and the difference is added to a total distance at step 514.

If the total distance does not exceed a threshold at step 516, steps 506 et seq. are repeated. As discussed above, the selection of the threshold involves a tradeoff. Again, a threshold of 100,000 meters is used in some embodiments.

If the threshold is exceeded at step 516, the revolution counter is read at step 518. The wheel circumference is then calculated by dividing the total distance by the number of revolutions from the revolution counter 120.

In the embodiment described above, the periods of time during which the total distance was traveled were contiguous such that one period began as soon as a previous period ended. This simplified the method by eliminating the necessity of reading the revolution counter at the beginning and end of each period. Those of skill in the art will recognize that it is not necessary for the periods to be contiguous and that the invention may also be practiced by using a plurality of non-

contiguous periods and reading the revolution counter at the beginning and end of each period (or, alternatively, resetting the revolution counter at the beginning of each period).

5 In the foregoing embodiments, positional inputs from the positioning system are used; however, it will be readily apparent that speed can also be used. For example, if the current speed S of the train is known from the positioning system, then the wheel size can be determined according to the equation $S = DF_r = 2\pi RF_r$, where D is the distance traveled in each rotation, F_r is the rotation frequency of the wheel, and R is the radius of the wheel. In practice, the speed from the
10 global positioning system may be read a number of times and the wheel size corresponding to each reading may be averaged. It should be noted that using speed rather than position information allows the wheel size to be determined more rapidly than using position information and is therefore preferable when wheel size is needed quickly (such as when a gross error has been detected). However, using
15 position information, especially over a long distance, results in greater accuracy. Accordingly, in some embodiments, speed is used to rapidly generate an initial estimate and position is used to generate a better estimate at a later time.

Furthermore, while track curvature and grade were determined by referencing a map database in the embodiments discussed above, it will be readily
20 recognized by those of skill in the art that curvature and grade can be determined from altitude and direction information provided by the global positioning system. For example, the track curvature may be determined by recording the train's position as reported by the positioning system at several times during the period in which data is collected. This position information can be used to construct a

curvature profile so that the amount of curvature can be determined after the data is collected. If the curvature is greater than a threshold, the data can be ignored, or, in some embodiments, can be corrected for the curvature such as by using the integration technique discussed herein. The same techniques can be used to
5 construct a grade profile.

It should also be noted that the invention may be incorporated into various types of train control systems, including the aforementioned PTC and ATC systems as well as many others.

In another embodiment of the invention, the wheel wear compensation
10 method is incorporated into a wheel revolution sensor signal distribution/
conversion system such as the QUIP™ system manufactured by the assignee of the present invention, Quantum Engineering. There may be several systems on board a train that input a signal representative of the wheel rotation and use that signal to calculate speed. For example, many locomotives that have been retro-fitted with a
15 train control system also are equipped with a separate speed display. Such systems typically require the conductor/engineer or maintenance personnel to measure the diameter of the train wheel to which the wheel sensor is attached and set DIP switches or otherwise configure the devices to indicate the wheel size. Because the wheel size changes over time as discussed above, these other devices must be
20 reconfigured on some periodic basis, thereby increasing labor costs.

Because there may be several systems that require the wheel sensor signal which together constitute a larger electrical load than the wheel sensor is capable of handling, and because some of these systems require an input signal of a different form than is supplied by the wheel sensor, signal conversion/distribution systems

such as the aforementioned QUIP™ distribution/conversion system have been devised. A substantial savings can be realized by modifying these distribution/conversion systems to output a modified signal that is representative of a wheel sensor signal would be generated by a wheel of a fixed size. Thus, for example, if the conversion/distribution system outputs a modified wheel sensor signal that is representative of a 40 inch wheel, each of the other systems that use the wheel sensor signal could be configured once for a 40 inch wheel and would thereafter not need to be periodically reconfigured.

Such a conversion/distribution system 300 is illustrated in Fig. 3. The system includes a control unit 110 connected to a wheel revolution sensor 320. In some embodiments, the wheel sensor 320 outputs a square wave, with each rising edge representing a revolution of the wheel. Thus, the time between leading edges represents the time taken for one full revolution of the wheel. It will be readily understood that the signal output by the wheel sensor 320 may be of many forms, analog or digital, and that the particular form of the signal is not important. Also connected to the control unit 110 is a GPS receiver 130 and a map database 140. The control unit 110 is configured to determine the wheel size using the method described in Fig. 2 or one of the other methods described herein. The control unit 110 determines the speed of the train, which can be taken from the GPS receiver 130 or can be determined with the knowledge of the previously determined wheel size. Using the actual speed of the train, the control unit 110 then determines the parameters necessary for a signal that would be representative of the signal that would be generated by the wheel sensor 320 if the wheel were a predetermined size such as 40". For example, where the wheel sensor outputs a square wave signal as

discussed above, the period of the square wave when the train is traveling 30 m.p.h. would be the distance traveled by one revolution, $2\pi \times 20$ inches, divided by the train speed, 30 m.p.h. or 528 inches/sec, which is equal to $125.7/528 = .238$ seconds. This .238 second period is supplied by the control unit 110 to a signal generator 180, which generates a square wave of the type discussed above with a period of .238 seconds. The signal generated by the signal generator 180 is then supplied to other systems A,B and C 191-193. Because the signal output by signal generator 180 will always be representative of a 40 inch wheel, it is not necessary to reconfigure the other systems 191-193 once they have been configured for a 40 inch wheel, thereby substantially reducing labor costs associated with these operations.

In the embodiment discussed above, speed is determined as part of the process of determining the parameters of the signal to be generated by the signal generator 180. It will be readily apparent to those of skill in the art that the parameters can be determined without actually calculating the speed. For example, once the wheel size is determined using the method of Fig. 2, that wheel size can be used to form a ratio of the predetermined wheel size to the actual wheel size. Thus, for example, if the predetermined wheel size is 40 inches, and the actual wheel size is 36, the ratio would be $40/36$. The control unit can then measure the period of the square wave and multiply the period by the ratio to determine the period of the signal that would be generated by the wheel sensor 320 if the wheel were actually 40 inches, and supply this period to the signal generator 180 to generate this signal.

As discussed above, it is possible to generate a signal for the other devices without using the signal from the wheel sensor 320. That is, the speed can be determined from the positional system (e.g., GPS receiver 130) and the parameters of the desired signal can be sent to the signal generator so that a signal can be
5 generated and distributed to the other systems, all without an actual wheel rotation sensor 320. This allows the system to serve as a back up for situations where the wheel sensor fails. This also allows the wheel sensor to be replaced, but such a system has the drawback that it will not provide a correct signal when the GPS system is not operational.

10 Obviously, numerous modifications and variations of the present invention are possible in light of the above teachings. It is therefore to be understood that within the scope of the appended claims, the invention may be practiced otherwise than as specifically described herein.

WHAT IS CLAIMED IS:

1. A method for determining a size of a wheel on a train comprising the steps of:

determining a linear distance traveled by a train during a period of time by
5 calculating a difference in positions reported by a positioning system located on the train at a start of the period and an end of the period;

repeating the determining step a plurality of times;

adding the linear distance from each of the determining steps to form a total distance; and

10 calculating the wheel size based on the total distance and a total number of wheel revolutions occurring during each of the determining steps.

2. The method of Claim 1, wherein the determining steps are performed successively with no separation between each period.

3. The method of Claim 1, wherein the determining steps are performed
15 with a separation between at least two successive periods for which a difference is calculated in the determining step.

4. The method of Claim 1, wherein the positioning system is a global positioning system.

5. The method of Claim 1, in which no portion of the total distance
20 corresponds to a section of track having a grade exceeding a grade threshold.

6. The method of Claim 5, further comprising the step of obtaining the grade from a track database using a position from the positioning system as an index.

7. The method of Claim 1, wherein the period is one second.

8. A system for determining a size of a train wheel comprising:
- a control unit;
 - a positioning system in communication with the control unit, the positioning system being configured to provide the control unit with positioning information pertaining to the train; and
 - a revolution counter connected to the control unit, the revolution counter being configured to measure rotation of a train wheel;
- wherein the control unit is configured to perform the steps of:
- determining a linear distance traveled by a train during a period of time by calculating a difference in positions reported by the positioning system at a start of the period and at the end of the period;
 - repeating the determining step a plurality of times;
 - adding the linear distance from each of the determining steps to form a total distance; and
 - calculating the wheel size based on the total distance and a total number of wheel revolutions occurring during each of the determining steps.
9. The system of Claim 8, wherein the determining steps are performed successively with no separation between each period.
10. The system of Claim 8, wherein the determining steps are performed with a separation between at least two successive periods for which a difference is calculated in the determining step.
11. The system of Claim 8, wherein the positioning system is a global positioning system.

12. The system of Claim 8, wherein no portion of the total distance corresponds to a section of track having a grade exceeding a grade threshold.

13. The system of Claim 8, further comprising the step of obtaining the grade from a track database using a position from the positioning system as an index.

14. The system of Claim 8, the period is one second.

15. A method for determining the size of a train wheel comprising the steps of:

inputting a speed from a positioning system installed on a train;

obtaining rotation information from a tachometer;

determining a wheel size based on the rotation information and the speed.

16. The method of Claim 15, further comprising the steps of repeating the inputting, obtaining and determining steps a predetermined number of times and calculating an average of the wheel sizes determined in the determining step.

17. The method of Claim 15, wherein the tachometer measures a rotation speed of the train wheel.

18. The method of Claim 15, wherein the tachometer measures a rotation speed of a motor connected to drive the train wheel.

19. The method of Claim 15, wherein the tachometer measures a rotation speed of a driveshaft connected to the train wheel.

20. The method of Claim 15, wherein the tachometer measures a rotation speed of a gear connected to the train wheel.

21. The method of Claim 15, wherein the wheel size based on the rotation information and the speed is used as an initial estimate, and further comprising the steps of:

obtaining a first position from the positioning system;

5 obtaining a second position from the positioning system;

calculating a distance between the first position and the second position;

and

calculating an updated wheel size based at least in part on the distance and a number of wheel revolutions occurring between the first position and the second position.

10

22. A method for supplying a corrected wheel sensor signal comprising the steps of:

determining a speed of a train;

determining a parameter of a signal that would be output by a wheel sensor

15 connected to a wheel of a predetermined size if the wheel were on the train;

generating a corrected wheel sensor signal having the parameter;

supplying the corrected wheel sensor signal to at least one device configured to accept a wheel sensor signal from a wheel sensor connected to a wheel of the predetermined size.

20 23. The method of Claim 22, wherein the speed of the train is obtained from the positioning system.

24. The method of Claim 22, wherein the speed of the train is determined using a wheel size determined by a method comprising the steps of:

a control unit;

a positioning system in communication with the control unit, the

5 positioning system being configured to provide the control unit with position information pertaining to the train; and

a revolution counter connected to the control unit, the revolution counter being configured to measure rotation of a train wheel;

wherein the control unit is configured to determine a size of the wheel
10 based on a distance traveled as measured by the positioning system and wheel rotation information measured by the revolution counter.

ABSTRACT

A method and system for compensating for wheel wear uses position and/or speed information from an independent positioning system to measure some distance over which the train has traveled. Wheel rotation information is also collected over the distance. The wheel rotation information and distance and/or speed information are then used to determine the size of the train wheels. The method is performed periodically to correct for changes in wheel size over time due to wear so that the wheel rotation information can be used to determine train position and speed in the event of a positioning system failure.

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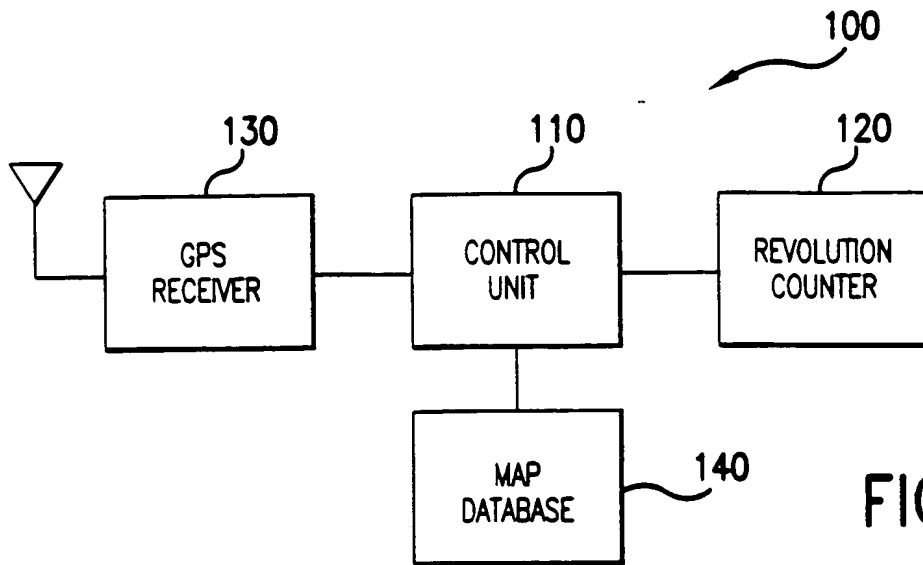


FIG.1

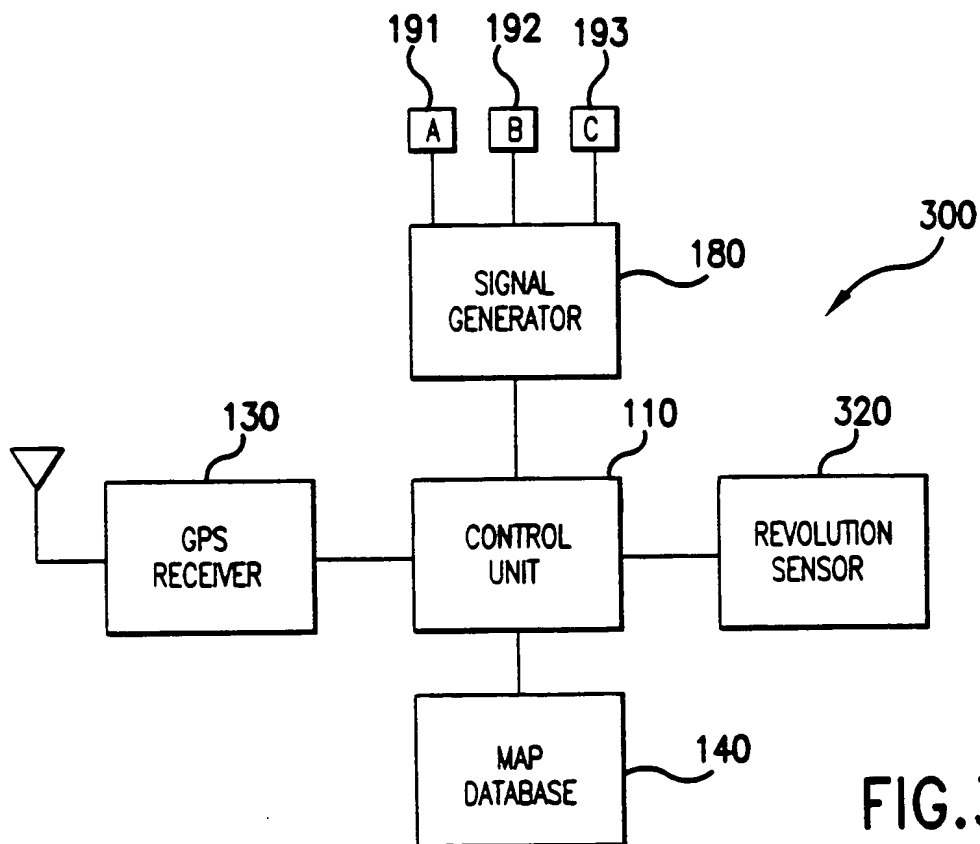


FIG.3

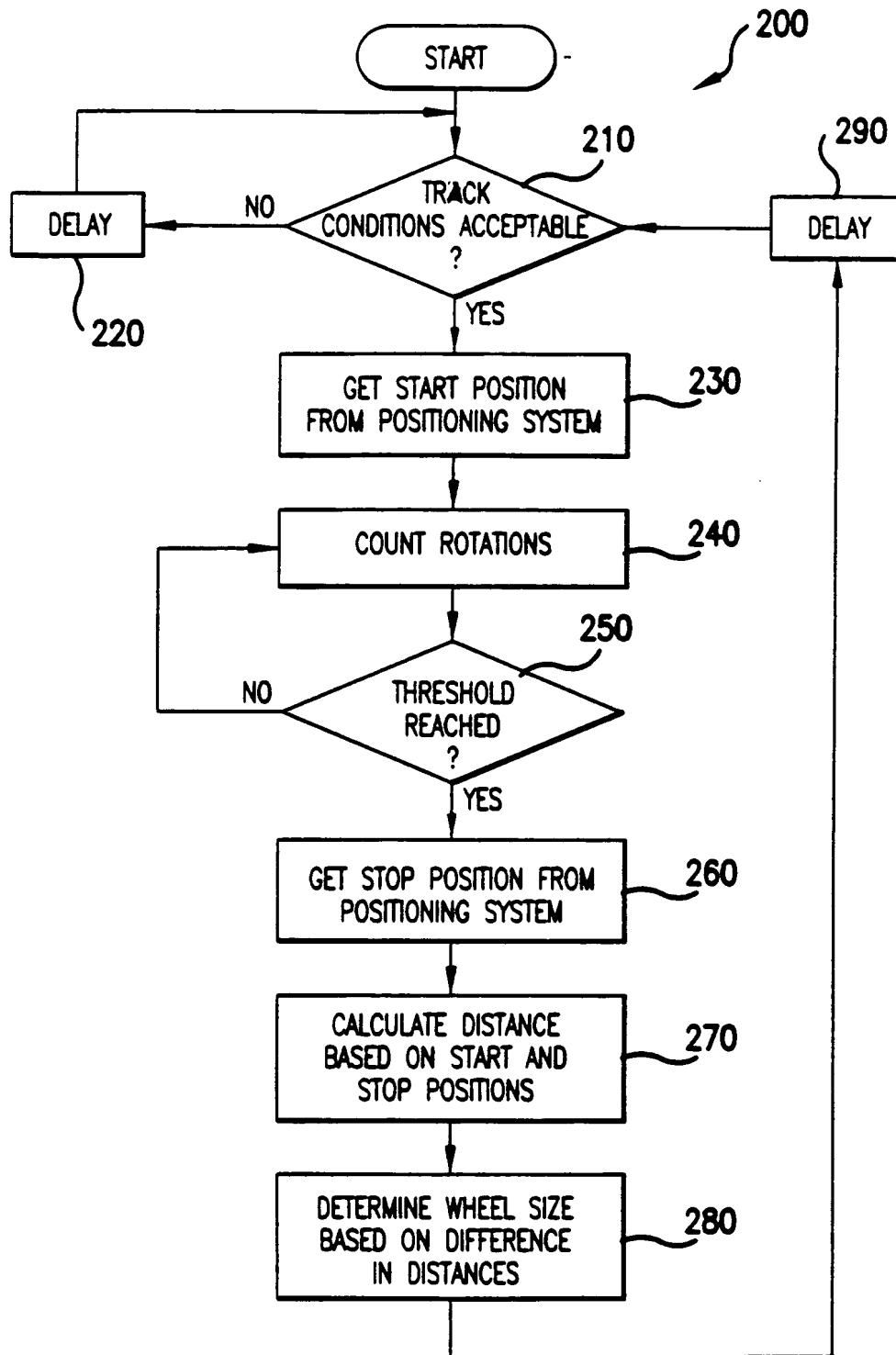


FIG.2

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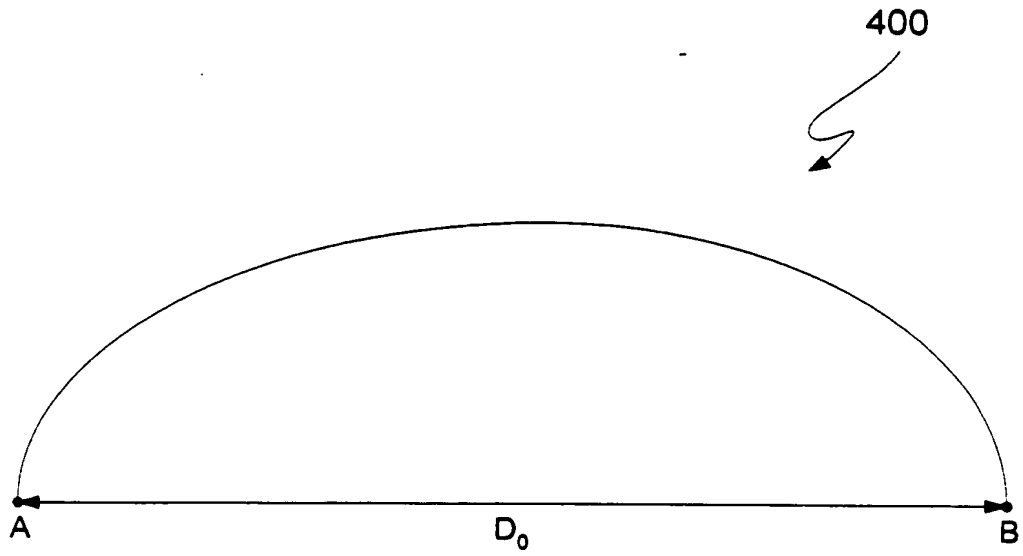


FIGURE 4(a)

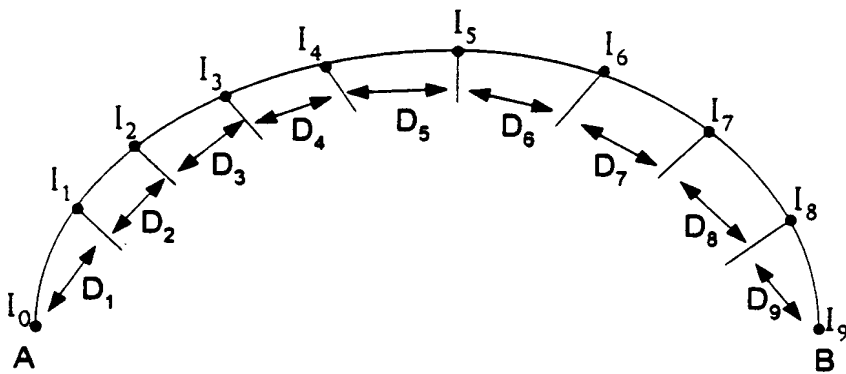


FIGURE 4(b)

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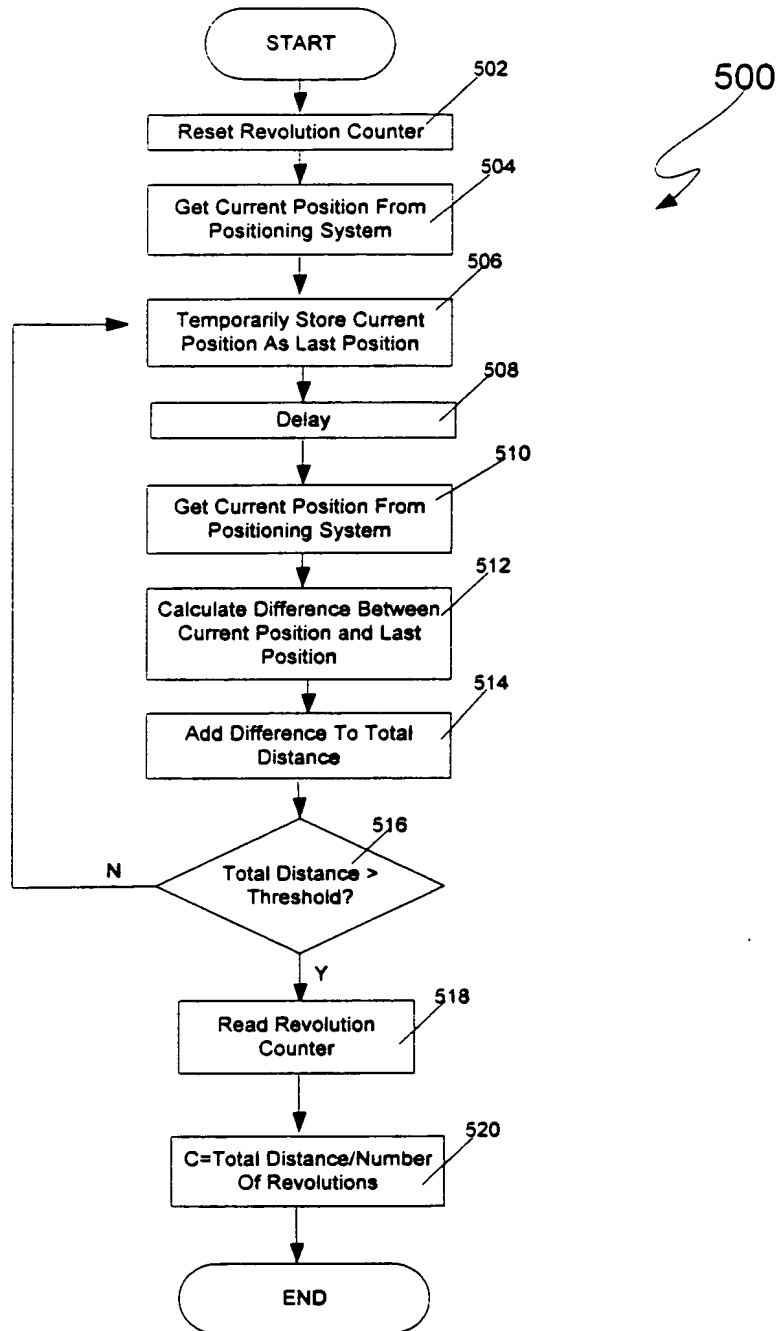


FIGURE 5

DOCKET NO: 3805-010-27 ✓

TITLE OF THE INVENTION

LIFTING RESTRICTIVE SIGNALING IN A BLOCK

BACKGROUND OF THE INVENTION

Field of the Invention

5 The invention relates to railroads generally, and more particularly to signal compliance train control methods and systems.

Discussion of the Background

 Many methods for controlling trains are known. Such methods include the Automated Block Signaling (ABS) and Centralized Train Control (CTC) methods.

10 In such methods, train tracks are divided into sections, referred to in the art as blocks, and an operator is relied upon to move a train in compliance with wayside signals that are positioned some distance before a block boundary. In traditional ABS and CTC systems and the like, the wayside signals comprise colored lights that are visually observed by the operator. In more modern variants of these

15 systems, sometimes generically referred to as communication-based train control (CBTC) systems, the signal information is transmitted into the cab of a locomotive. Examples of such systems include cab signaling systems and the TRAIN SENTINEL™ system available from the assignee of the present application, Quantum Engineering, Inc. Some of these systems, including the TRAIN

20 SENTINEL™ system, ensure operator compliance with signal information transmitted into the cab.

Such block-oriented systems vary in their implementation. However, one aspect shared by several of these systems is that a restrictive signal in one block may be caused by conditions in the next block. A problem shared by such known systems is that there is no provision for lifting the restrictive signal in a block if
5 conditions in the next block causing the restrictive signal "clear up." Causing a train to operate under a restrictive signal unnecessarily makes operation of the train less efficient, which increases costs.

What is needed is a method and apparatus that allows the lifting of a restrictive signal after a block has been entered when such restrictive signal is no
10 longer necessary, and that allows a less restrictive signal to be recognized even after a train has passed the aforementioned wayside signal device.

SUMMARY OF THE INVENTION

The present invention meets the aforementioned need to a great extent by providing a computerized train control system that uses signal information from a
15 next block to change a restrictive signal in a block currently occupied by the train to a less restrictive signal if it can be ascertained that the condition causing the more restrictive signal has changed. This may be accomplished by receiving signal information from the next block while still in the current block and, if the signal information from the next block is no more restrictive than the signal information
20 in the current block and if the signal for the current block is of a type that can safely be modified, allowing the train to operate as if the signal information for the current block were less restrictive than the actual, previously received signal information for the current block. In preferred embodiments of the invention,

wayside signal devices transmit messages including signal information and identification information in order to allow the system to unambiguously determine that the signal information in the message corresponds to the next wayside signal device.

5

BRIEF DESCRIPTION OF THE DRAWINGS

A more complete appreciation of the invention and many of the attendant features and advantages thereof will be readily obtained as the same become better understood by reference to the following detailed description when considered in connection with the accompanying drawings, wherein:

10

Figure 1 is a schematic diagram showing a portion of train track divided into a plurality of blocks according to one known signaling method.

Figure 2 is a logical block diagram of a train control system according to one embodiment of the invention.

15

Figure 3 a flow chart of an automatic fault reporting method performed by the system of Figure 2.

DETAILED DESCRIPTION

The present invention will be discussed with reference to preferred embodiments of train control systems. Specific details, such as types of signaling systems, are set forth in order to provide a thorough understanding of the present invention. The preferred embodiments discussed herein should not be understood to limit the invention. Furthermore, for ease of understanding, certain method

20

steps are delineated as separate steps; however, these steps should not be construed as necessarily distinct nor order dependent in their performance.

Referring now to the drawings, wherein like reference numerals designate identical or corresponding parts throughout the several views, Figure 1 illustrates a traditional ABS system 10 in which a train track 20 that has been divided into three blocks 30, 40, 50 labeled "A," "B" and "C," respectively. A wayside signal 32, 42 and 52 is associated with each of the blocks 20, 40 and 50. The wayside signals 32, 42, 52 include colored lights to provide visual signal information to operators on trains approaching the signals. The signal 52 for block C 50 will be red if a train 60 is in block C 50 or if a broken rail has been detected in block C 50. A red signal means stop before entering the block.

When the signal 52 in block C 50 is red, the signal 42 in block B 40 is yellow, which signifies that speed should be reduced in preparation for stopping prior to entering the next block C 50. The signal 32 in block A 30 will be green, which signifies no restriction is in place for that block and a train may proceed through the block at maximum authorized speed. The blocks are traditionally sized such that a train may be brought to a stop within one block under worst case conditions (e.g., maximum speed, maximum train weight, etc.), thereby ensuring that a train that had been proceeding at full speed upon entering a yellow block can be brought to a stop before entering a next block if the next block is red.

It will be recognized by those of skill in the art that other, more complex signaling systems are known. For example, in the aforementioned CTC system, there are several intermediate signals (signals other than red or stop on the one hand and green or proceed without restriction on the other hand) rather than just

the single yellow intermediate signal. Also, while some systems use fixed blocks (e.g., blocks whose boundaries are predetermined and static and are usually associated with landmarks such as specific mileposts or junctions points), dynamic block systems are also known and within the scope of the invention.

5 Because of its simplicity, the ABS system discussed above will be used to illustrate the invention; however, it should be recognized that the invention is not so limited and can be used with a wide variety of signaling systems and techniques including but not limited to those discussed above.

10 In the present invention, the wayside signals 32, 42, 52 have the ability to transmit messages including the signal information and, preferably, an identification number to the train in addition to or in place of the colored lights discussed above. Preferably these signals 32, 42, 52 transmit such messages in response to interrogation signals, but the invention is not so limited. In other embodiments of the invention, the signals are equipped to detect the presence of a
15 train and transmit a signal message automatically. In other embodiments, a message is broadcast repeatedly regardless of whether a train is present. In yet other embodiments, a central authority monitors the locations of trains in the system and instructs the switches 32, 42, 52 to transmit a message as the train approaches.

20 Figure 2 is a logical block diagram of a train control system 100 according to an embodiment of the present invention. The system 100 includes a control module 110, which typically, but not necessarily, includes a microprocessor. The control module 110 is responsible for controlling the components of the system.

The system 100 preferably includes a positioning system 120 connected to the control module 110. The positioning system supplies the position (and, in

some cases, the speed) of the train to the control module 110. The positioning system 120 can be of any type, including a global positioning system (GPS), a differential GPS, an inertial navigation system (INS), or a Loran system. Such positioning systems are well known in the art and will not be discussed in further detail herein. (As used herein, the term “positioning system” refers to the portion of a positioning system that is commonly located on a mobile vehicle, which may or may not comprise the entire system. Thus, for example, in connection with a global positioning system, the term “positioning system” as used herein refers to a GPS receiver and does not include the satellites that transmit information to the GPS receiver.)

A database 130 is also connected to the control module 110. The database 130 preferably comprises a non-volatile memory such as a hard disk, flash memory, CD-ROM or other storage device, on which data is stored. Other types of memory, including volatile memory, may also be used. The data stored in the database preferably includes boundaries of all blocks in the system and identification numbers for all associated signal devices. The data preferably also includes map data including information concerning the direction and grade of the track in the railway. By using train position information obtained from the positioning system 120 and the map database 130, the control module 110 can determine its position relative to blocks in the system as well as the identification numbers of signal devices associated with those blocks.

The control module 110 communicates with a signal devices such as device 32 associated with block A 30 (not shown in Fig. 2) through transceiver 150. The transceiver 150 can be configured for any type of communication, including

communicating through rails and wireless communication. In addition to communicating with signal devices, the transceiver 150 is also preferably capable of communicating with one or more dispatchers 190.

Also connected to the control module 110 is a brake interface 160. The
5 brake interface 160 monitors the train brakes and allows the control module 110 to activate and control the brakes to stop or slow the train when necessary.

An operator pendant 170 is also connected to the control module 110. The pendant 170 may take the form of the operator display illustrated in co-pending U.S. application serial number 10/186,426, entitled "Train Control System and
10 Method of Controlling a Train or Trains" filed July 2, 2002, the contents of which are hereby incorporated by reference herein. The pendant 170 may be used to display signals from the signal devices 32, 42, 52 to the operator and to provide other messages to the operator and receive certain inputs from the operator as will be discussed in further detail below.

15 Figure 3 is a flowchart 300 illustrating operation of the control module 110 in connection with signal devices 32, 42, 52. It should be understood that the control module 110 performs steps in addition to those shown in Figure 3 to ensure that the train complies with the signals it receives from the wayside signal devices 32, 42, 52. The control module 110 get the train's position from the positioning
20 system 120 at step 310. Using the position reported by the positioning system, the control module then retrieves the location of the next signal device 32, 42, 52 from the database 130 at step 311. If the train is not within communication range of the next signal device 32, 42, 52 (e.g., the distance between the train's position and the location of the next signal device is less than a threshold distance) at step 312, the

control module 110 gets an updated train position from the positioning system 120 at step 313 and repeats step 312 until the next signal device is within range at step 312. When the next signal device is within communications range at step 312, the control module 110 sends an interrogation message, preferably containing an
5 identification number of the next signal device, at step 314. If no valid response (a valid response means a response that includes the correct identification number for the next signal device and does not indicate any errors) is received at step 315, the control module 110 warns the operator of the condition at step 316 and, unless the operator acts first, stops the train before reaching the next block boundary at step
10 317 by activating the train's brakes via the brake interface 160 and notifying the dispatcher 190 at step 318.

If a valid response is received at step 315, the response is stored in a temporary database at step 319 and is compared to a previously stored signal for the current block (that is, the signal before the train entered the block) at step 320.
15 If the next signal is more restrictive at step 321, then steps 310 et seq. are repeated. If the signal for the next block is not more restrictive than the current signal at step 321, and the signal for the current block is modifiable at step 322, then the signal for the current block is changed to a less restrictive signal at step 324 and the operator is notified of the change at step 326.

20 It is important to note that not all signals are modifiable; that is, not all signals can be modified safely. For example, in some systems, a "red" or "stop" signal in a block before the train enters the block might be caused by another train in the block or might be caused by a broken rail in the block. In a system in which the signal device 32, 42, 52 does not provide information as to the reason for such

a red signal, the red signal cannot be safely modified, or lifted, regardless of the signal in the next block. On the other hand, a yellow signal in a block is only caused by a red signal in a next block. Thus, if a train is in a block for which the signal was yellow before the train entered (of course, the signal in the block will
5 change to red once the train enters the block) and the signal for the next block changes from red to either yellow or green (which signifies that either a train has left the next block or the broken rail or other problem has been corrected), the signal for the current block can be changed to a less restrictive signal. In more complex signaling systems, determining whether a signal is modifiable may be
10 more complex.

In the example above, the yellow intermediate signal is changed to green, which is the least restrictive signal. In more complex systems with multiple intermediate signals, the signal may be changed to a less restrictive signal rather than to the least restrictive signal. As with the determination as to whether a signal
15 is modifiable, the determination as to how to modify the signal may vary depending upon the exact nature and complexity of the signal system.

It should be noted that changing or modifying the signal, as discussed above with respect to step 324, means allowing the train to proceed as if the signal transmitted by the wayside signal device had been changed. This may be
20 accomplished, for example, by modifying the value of the signal as reflected in the temporary database in the system 100. Causing a change in the signal actually being transmitted by the wayside signal device is not required for this step.

Once the signal for the current block has been modified at step 324, the operator is notified of the change at step 326. The notification is preferably accomplished using the operator pendant 170.

5 In some embodiments of the invention such as the embodiment discussed above, a wayside signal device is interrogated as the train approaches. However, the invention is not limited to such embodiments. In some other embodiments, wayside signal devices continuously or periodically transmit signal information regardless of whether a train is close enough to receive such information. In yet other embodiments, wayside signal devices detect when a train is approaching
10 (using, e.g., track circuits or radar detectors) and transmit signal information at that time. In still other embodiments, a central authority tracks movement of trains and commands the wayside signal devices to transmit the signal information when a train is approaching. Other techniques for triggering the transmission of signal information from wayside signal devices are also possible and within the scope of
15 the invention.

In the embodiments discussed above, the control module 110 is located on the train. It should also be noted that some or all of the functions performed by the control module 110 could be performed by a remotely located processing unit such as a processing unit located at a central dispatcher 190. In such embodiments,
20 information from devices on the train (e.g., the brake interface 160) is communicated to the remotely located processing unit via the transceiver 150.

Obviously, numerous modifications and variations of the present invention are possible in light of the above teachings. It is therefore to be understood that

within the scope of the appended claims, the invention may be practiced otherwise than as specifically described herein.

WHAT IS CLAIMED IS:

1. A system for controlling a train, the system comprising:
a control unit; and
a receiver, the receiver being located on the train and being in
5 communication with the control unit;
wherein the control unit is configured to perform the steps of
receiving signal information for a next block via the receiver;
determining whether the signal information for a current block is
modifiable;
10 determining whether the signal information for the next block is less
restrictive than the signal information for the current block; and
changing the signal information for the current block to a less
restrictive signal if the signal information for the current block is modifiable and
the signal information for the next block is not more restrictive than the signal
15 information for the current block.
2. The system of Claim 1, further comprising a display in communication
with the control unit, wherein the control unit is further configured to perform the
step of notifying an operator that the signal information for the current block has
been changed by displaying a message on the display.
- 20 3. The system of Claim 1, wherein the signal information is received from
a wayside signal device.
4. The system of Claim 3, further comprising a transmitter connected to the
control unit, wherein the control unit is further configured to transmit an
interrogation message to the wayside signal device via the transmitter.

5. The system of Claim 4, further comprising a positioning system in communication with the control unit and a database including locations of wayside signal devices, the control unit being in communication with the database, wherein the control unit is further configured to perform the step of determining when to
5 transmit the interrogation message to the wayside signal device based on information obtained from the database and the positioning system.

6. The system of Claim 5, wherein the positioning system is a global positioning system.

7. The system of Claim 5, wherein the interrogation message includes an
10 identification number of the wayside signal device and the control unit is further configured to retrieve the identification number of the wayside signal device from the database.

8. The system of Claim 1, wherein the signal information is changed to a less restrictive signal.

15 9. The system of Claim 1, wherein the signal information is changed to a least restrictive signal.

10. A method for controlling a train comprising the steps of:
receiving signal information for a next block;
determining whether the signal information for the next block is less
20 restrictive than the signal information for a current block;
determining whether the signal information for the current block is modifiable; and

allowing the train to proceed in the current block as if the signal information for the current block were less restrictive than actual signal

information for the current block if the signal information for the current block is modifiable and if the signal information for the next block is not more restrictive than the signal information for the current block.

5 11. The method of Claim 10, further comprising the step of notifying an operator that the signal information for the current block has been changed.

 12. The method of Claim 10, wherein the signal information is received from a wayside signal device.

 13. The method of Claim 12, further comprising the step of transmitting an interrogation message to the wayside signal device.

10 14. The method of Claim 13, further comprising the step of determining when to transmit the interrogation message to the wayside signal device based on location information for the wayside signal device obtained from a database and position information pertaining to the train from a positioning system.

15 15. The method of Claim 14, wherein the positioning system is a global positioning system.

 16. The method of Claim 14, wherein the interrogation message includes an identification number of the wayside signal device.

 17. The method of Claim 10, wherein the signal information is changed to a less restrictive signal.

20 18. The method of Claim 10, wherein the signal information is changed to a least restrictive signal.

ABSTRACT

A train control system and method uses signal information from a next block to change a restrictive signal in a block currently occupied by the train to a less restrictive signal if it can be ascertained that the condition causing the more restrictive signal has changed. This may be accomplished by receiving signal information from the next block while still in the current block and, if the signal information from the next block is no more restrictive than the signal information in the current block, and the signal in the current block is of a type that can safely be modified, allowing the train to operate as if the signal information for the current block were less restrictive than the actual, previously received signal information for the current block.

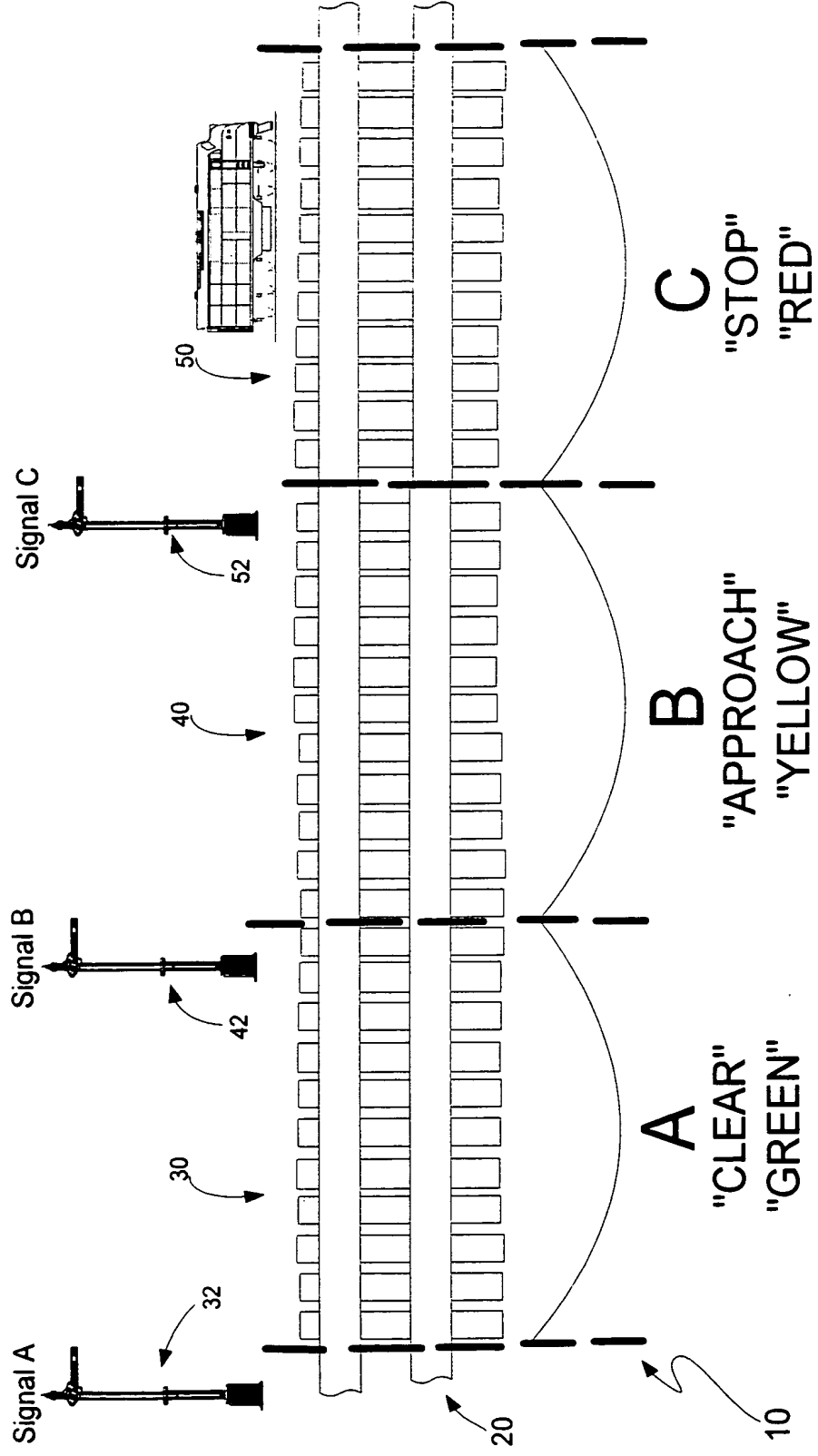


FIGURE 1

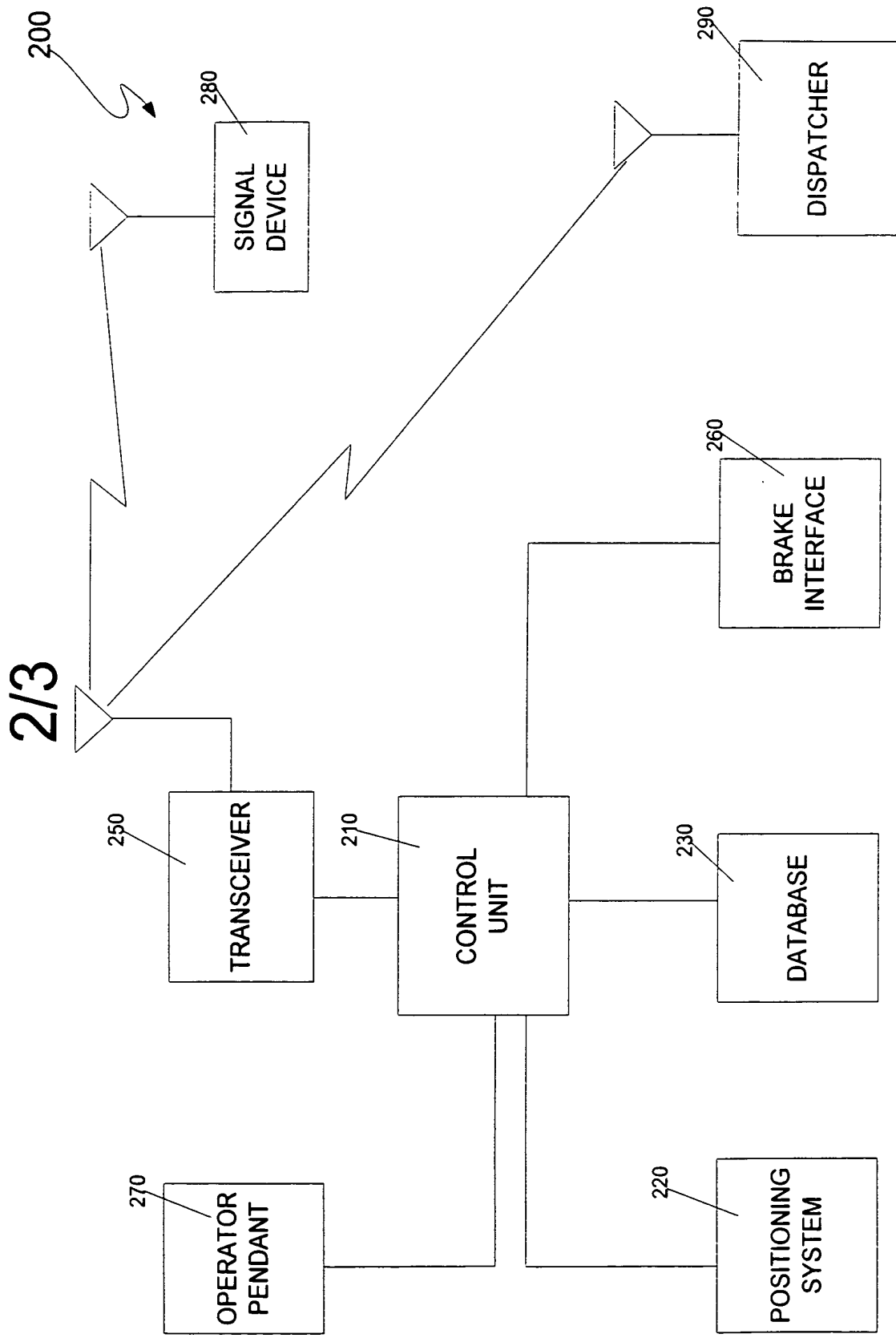


Figure 2

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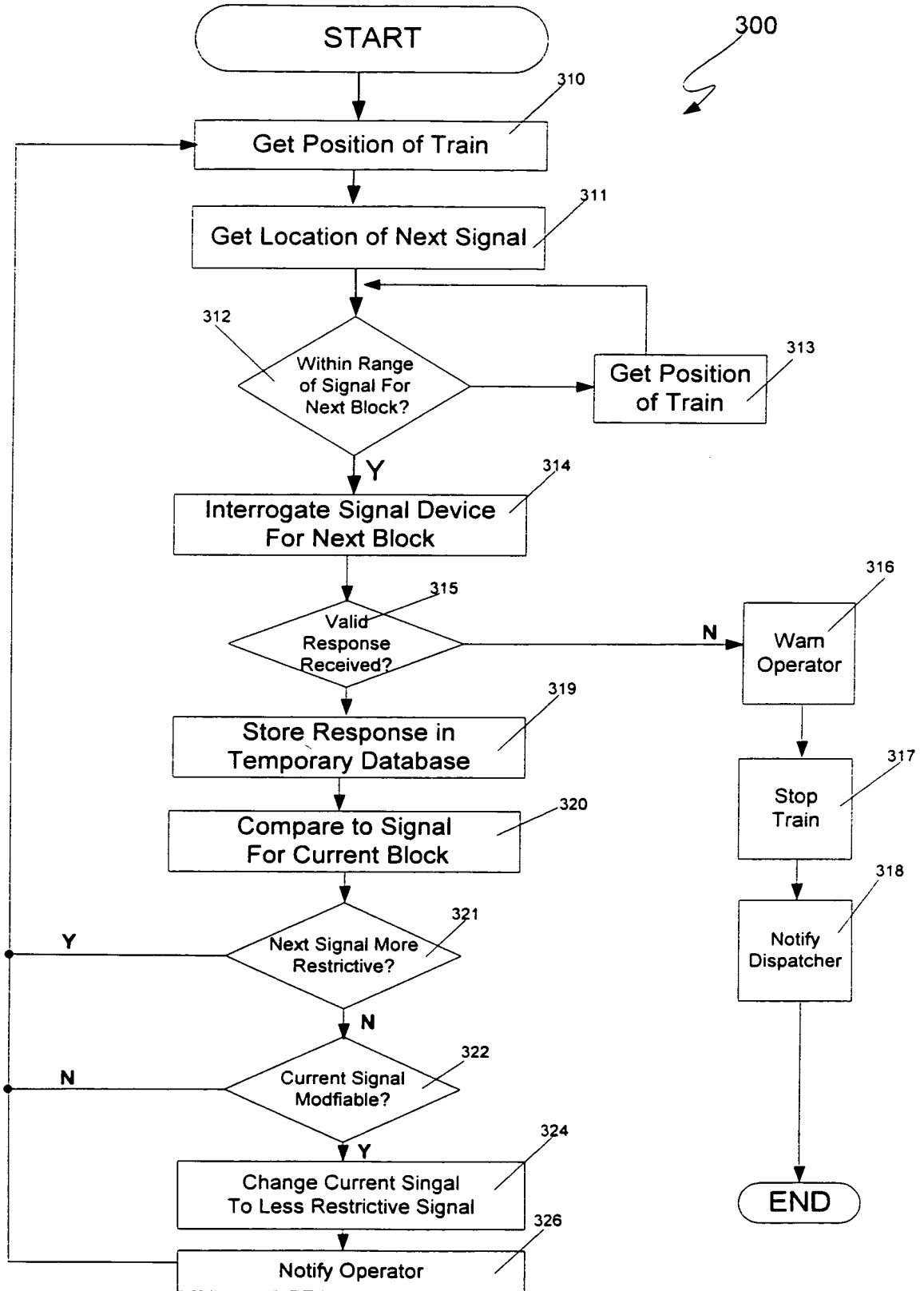


Figure 3

✓
DOCKET NO: 3805-006-27

TITLE OF THE INVENTION

**METHOD AND SYSTEM FOR
DETECTING WHEN AN END OF TRAIN HAS PASSED A POINT**

BACKGROUND OF THE INVENTION

5 **Field of the Invention**

The invention relates to railroads generally, and more particularly to a method and system for detecting when an end of train passes a point such as a mile marker, switch, siding or other location of interest.

Discussion of the Background

10 It is often important to be able to determine that a railroad has passed a particular point in a railroad. For example, in a train control method known as Track Warrant Control (TWC), a railroad is divided into sections referred to as blocks and a dispatcher gives each train warrants, or authorities, to occupy and/or move in one or more blocks. The blocks are usually (but not necessarily) fixed,
15 with block boundaries usually (but not necessarily) being identified with physical locations on the railroad such as mileposts, sidings, and switches. In this system, a train in a first block (or group of blocks) receives a warrant to occupy a second adjacent block (or group of blocks) from the dispatcher and informs the dispatcher when it has cleared the first block and has entered the following block. After the
20 train notifies the dispatcher that the first block has been cleared, the dispatcher may issue an unrestricted (rather than a "joint" or "permissive" warrant) warrant to occupy the first block to a second train. If such a warrant to occupy the first block is issued to the second train before the end of the first train has cleared that block, a

collision between the two trains may result. Therefore, determining that the end of the train has left a block is critical in a track warrant control system.

As another example, it may be necessary to wait until one train has passed a switch so that the switch position can be set in a different direction for a following train. There are yet other examples in which it is necessary to determine that an
5 end of train has passed a point such as the end of a block.

Determining that an end of a train has passed a point is not a trivial process. Modern trains can be hundreds of yards long, and an engineer in the lead locomotive often cannot see the end of the train. Operating trains at night or
10 during bad weather may also make visually determining that the end of a train has passed a point difficult or impossible. Thus, visual methods are not sufficient.

A second method used to determine that the end of a train has passed a point is to determine how far the head of the train has traveled past the point using a wheel tachometer/revolution counter or a positioning system (e.g., a GPS
15 system). With this method, once the head of the train has traveled a distance equal to the length of the train past the point, it is assumed that the end of the train has passed the point. However, with this method, it is important to take into account the possibility that one or more end cars of a train may become uncoupled from the remainder of the train.

20 One way in which uncoupled cars can be detected is through the use of end-of-train, or EOT, devices equipped with motion detectors. These devices, which communicate via radio with the head of the train (HOT), provide an indication as to whether or not the end of the train is in motion. However, with these devices the motion sensors sometimes break or give false readings and, under

certain circumstances, may mislead a conductor or engineer even when working properly. One potentially disastrous incident known to the inventors in which even a properly functioning motion detector can give a misleading indication involves a distributed power train. A distributed power train is a train comprising one or more locomotives placed at the front of the train, followed by one or more cars, followed by one or more additional locomotives and cars. In such a train, the throttles in the second group of locomotives are operated by remote control to be in the same position as the throttles in the first group.

In the above-referenced incident, a distributed power train was temporarily stopped at a crossing. While stopped, a vandal disconnected the second group of locomotives from the preceding car and closed off the valves in the air brake line (had these valves not been closed off, a failsafe mechanism would have activated the brakes to prevent the train from moving). In this particular distributed power train, the second group of cars connected to the second group of locomotives was heavier than the first group of cars connected to the first group of locomotives. Because the second group of cars was heavier than the first, there was a difference in speed between the two portions of the train when the train began moving after being uncoupled by the vandal, and the first portion of the train began to separate from the second portion. The EOT motion sensor transmitted the correct status that the EOT (last car) was moving, but did not (indeed, could not) indicate the train was separated. In this incident, the separation grew to over a mile before the engineer noticed that there was a problem.

If the engineer on this train had relied on the distance traveled by the head of the train to report to the dispatcher that the end of the train had cleared the

previous block, then an extremely dangerous situation would have resulted in that the end of the separated train would still have been in the previous block where an oncoming train might have collided with it. Thus, any method used to determine that the end of the train has passed a point should take into account the possibility
5 that the end of the train may have become separated from the head of the train.

One method for detecting that a train has passed a point is discussed in U.S. Patent No. 6,081,769. In this method, discussed at col. 4, lines 49-67, a second GPS receiver is placed on the end of the train and the position reported by that receiver is used to determine that the end of the train has passed the point of
10 interest. This patent also discloses that the difference in position reported by the first and second GPS receivers can be used to determine the length of the train.

SUMMARY OF THE INVENTION

The present invention determines that an end of train has passed a point through the use of positioning systems located at the head of the train and the end
15 of the train. In a first method, a control unit will obtain the train's position at a point of interest (e.g., a switch or block boundary) from the HOT positioning system. The control unit will then determine when the train has traveled a distance equal to the length of the train. This can be done either by integrating successive reports from the positioning system (that is, determining a difference in position
20 between successive reports and adding the differences to determine a total distance), or by periodically determining a distance between the position of the point of interest and the position reported by the positioning system until such time as the distance is greater than the length of the train. When the distance traveled by

the head of the train equals or exceeds the length of the train, the control unit will interrogate the positioning system at the end of the train. If the difference between this position and the position reported by the head-of-train positioning system at the point of interest exceeds a threshold, then the end of the train has passed the point. While it is possible to set the threshold to zero, the threshold is chosen to include a safety factor to account for, among other things, positioning system errors. As an additional check, the speeds reported by the end-of-train and head-of-train positioning systems can be compared to verify that the difference in speeds is approximately zero (a small difference is preferably allowed to account for positioning system errors and slack between cars which can allow the cars at the end of the train to have a slightly different speed as compared to the locomotive at the head of the train at any given moment).

In a second method, when the HOT positioning system reaches a point of interest, the position reported by the EOT positioning system is integrated until the total distance traveled by the end of the train equals the length of the train (again, a safety factor is preferably included). If the speed reported by the EOT positioning system matches (allowing for positioning system errors) the speed reported by the HOT positioning system when the integrated distance equals the length of the train, the end of the train has passed the point.

BRIEF DESCRIPTION OF THE DRAWINGS

A more complete appreciation of the invention and many of the attendant features and advantages thereof will be readily obtained as the same become better

understood by reference to the following detailed description when considered in connection with the accompanying drawings, wherein:

Figure 1 is a logical block diagram of a system for determining that the end of a train has passed a point according to one embodiment of the invention.

5 Figure 2 is a flow chart of a method for determining that an end of a train has passed a point that is performed by the system of Figure 1.

Figure 3 is a flow chart of a method for determining that an end of a train has passed a point that is performed by the system of Figure 1 according to a second embodiment of the invention.

10 Figure 4 is a flow chart of a method for determining that an end of a train has passed a point that is performed by the system of Figure 1 according to a third embodiment of the invention.

DETAILED DESCRIPTION

15 The present invention will be discussed with reference to preferred embodiments of the invention. Specific details, such as types of positioning systems and threshold distances, are set forth in order to provide a thorough understanding of the present invention. The preferred embodiments discussed herein should not be understood to limit the invention. Furthermore, for ease of understanding, certain method steps are delineated as separate steps; however,
20 these steps should not be construed as necessarily distinct nor order dependent in their performance.

Referring now to the drawings, wherein like reference numerals designate identical or corresponding parts throughout the several views, Figure 1 is a logical

block diagram of a train control system 100 according to an embodiment of the present invention. The system 100 includes a control module 110 which typically, but not necessarily, includes a microprocessor. The control module 110 is responsible for controlling the other components of the system and performing the mathematical calculations discussed further below.

A head of train positioning system 120 and an end of train positioning system 130 are connected to the control module 110. The positioning systems supply the position and, preferably, the speed of the train to the control module 110. The positioning systems 120, 130 can be of any type, including global positioning systems (GPS), differential GPSs, inertial navigation systems (INS), or Loran systems. Such positioning systems are well known in the art and will not be discussed in further detail herein. (As used herein, the term “positioning system” refers to the portion of a positioning system that is commonly located on a mobile vehicle, which may or may not comprise the entire system. Thus, for example, in connection with a global positioning system, the term “positioning system” as used herein refers to a GPS receiver and does not include the satellites that transmit information to the GPS receiver.)

A map database 140 is also connected to the control module 110. The map database 130 preferably comprises a non-volatile memory such as a hard disk, flash memory, CD-ROM or other storage device, on which map data is stored. Other types of memory, including volatile memory, may also be used. The map data preferably includes positions of all points of interest such as block boundaries, switches, sidings, etc. The map data preferably also includes information concerning the direction and grade of the track in the railway. By using train

position information obtained from the positioning systems 120, 130 and information from the map database 140, the control module 110 can determine its position relative to points of interest.

Some embodiments of the invention also include a transceiver 150
5 connected to the control module 110 for communicating with a dispatcher 160. The transceiver 150 can be configured for any type of communication, including communication through rails and wireless communication.

Also connected to the control module 110 in some embodiments of the invention is a warning device 170. The warning device 170 is used to alert the
10 operator to a possible error condition such as the separation of the EOT from the HOT. The warning device 170 may comprise audible warning devices such as horns and beepers and/or visual warning devices such as lights or alphanumeric and graphic displays.

Figure 2 is a flowchart 200 illustrating operation of the control module 110
15 according to one embodiment of the invention. The control module 110 determines the location of the next point of interest at step 200. The next point of interest may be determined in any number of ways including, for example, using information from the map database 140, or it may be obtained from a dispatcher (e.g., in a warrant/authority). The control module then obtains the train's current
20 position from information provided by the HOT positioning system 120 at step 212. If the current train position as reported by the HOT positioning system 120 indicates that the HOT has not yet reached the point of interest at step 214, step 212 is repeated.

When the HOT has reached the point of interest at step 214, the control module then delays for a short period of time (e.g., 1 second) at step 215 and obtains the current HOT position from the HOT positioning system 120 at step 216. This position is compared with the HOT position at the point of interest at step 218. If the difference is not greater than a length of train threshold at step 220, step 216 is repeated. The length of train threshold includes the length of the train and, preferably, a safety factor to account for positioning system errors. The length of the train may be reported to the control module 110 by the dispatcher, or the dispatcher's computer, may be entered manually by the operator, or may be determined using any other method, including the methods disclosed in U.S. Patents 6,081,769 and 6,311,109.

If the distance traveled by the HOT exceeds the length of the train at step 220, the position of the end of the train as reported by EOT positioning system 130 is obtained at step 222. This position is compared to the position obtained (at step 212) from the HOT positioning system at the point of interest at step 224. If this difference does not exceed a threshold at step 226, step 222 is repeated. The threshold utilized in step 226 is nominally zero but preferably includes a safety margin to account for positioning system errors.

If the difference exceeds the threshold at step 226 (signifying that the end of the train has passed the point of interest), the speeds reported by the EOT and HOT positioning systems is compared at step 228. The purpose of this comparison is to ensure that the EOT and HOT are not traveling at significantly different speeds, which would be indicative of a train separation. If the difference in EOT and HOT speeds is greater than a threshold (again, nominally zero but preferably including a

safety factor to account for differences in speed caused by slack between cars in train and positioning system errors) at step 230, then the control module 110 warns the operator of a possible train separation at step 232. If the difference in EOT and HOT speeds is less than the threshold at step 230, then the control module 110
5 reports (e.g., to the dispatcher 160 via the transceiver 150) that the end of the train has passed the point of interest at step 234.

Figure 3 is a flowchart of the operation of the control module 110 according to a second embodiment of the invention. The method illustrated in Figure 3 is similar to the method illustrated in Figure 2, but differs in the way in which the
10 control module 110 determines that the head-of-train has traveled a distance equal to the length of the train. The step in the method of Figure 2 can be performed by successively querying the GPS system to determine the distance between the point of interest and the current head-of-train location. The distance may be determined by simply calculating a linear distance, but doing so can be disadvantageous in that,
15 for curved sections of track, the linear distance will be shorter than the true “track distance” (i.e., the distance that the train has traveled over the track), which will result in an unnecessary delay in determining that the HOT has traveled a distance equal to the length of the train. This step may also be performed using track information stored in the map database 140 to calculate the true track distance, but
20 such calculations are necessarily more complex. In the method of Figure 3, an integration method is used whereby the differences in position over short distances is summed. This method has the benefit of using simple linear calculations but also approximates the true track distance because the calculations are performed frequently (e.g., every 1 second).

Referring now to Figure 3, steps 210-214 are the same as described above in connection with Figure 2. When the HOT has reached the point of interest at step 214, the HOT position is stored in a temporary register at step 315. The system then delays for a short period (e.g., 1 second) at step 316. The control
5 module 110 then obtains the current HOT position from the HOT positioning system 120 at step 317, subtracts this position from the previously stored HOT position at step 318, and adds the difference to the sum of total distance traveled at step 319. If the total distance traveled does not exceed a threshold equal to the length of the train plus a safety margin at step 320, the current HOT position is
10 stored in the temporary register at step 321 and steps 316 et seq. are repeated. If the sum of the total distance does exceed the threshold at step 320, steps 222 et seq., which are identical to the correspondingly-numbered steps in Figure 2, are repeated.

Figure 4 is a flowchart 400 illustrating the operation of the control module
15 110 according to a third embodiment of the invention. The control module 110 determines the location of the next point of interest at step 402. As discussed above, the next point of interest may be determined in any number of ways including, for example, using information from the map database 140, or it may be obtained from a dispatcher (e.g., in a warrant/authority). The control module 110
20 then obtains the train's current position from information provided by the HOT positioning system 120 at step 404. If the current train position as reported by the HOT positioning system 120 indicates that the HOT has not yet reached the point of interest at step 406, step 404 is repeated.

When the HOT has reached the point of interest at step 406, the control module 110 then obtains the current EOT position from the EOT positioning system 130 and temporarily stores it at step 408. The control module 110 then delays a short period (e.g., 1 second). After the delay, the current EOT position is obtained at step 412, the difference between this position and the previously stored EOT position is calculated at step 414 and this difference is added to a total distance (the total distance that the EOT has traveled since the HOT passed the point of interest) at step 416. If the total distance is not greater than a length of train threshold at step 418, the current EOT positioned is stored at step 420 and steps 410 et seq. are repeated.

If the distance traveled by the EOT exceeds the length of the train at step 418, the position of the end of the train as reported by EOT positioning system 130 is compared to the position obtained (at step 406) from the HOT positioning system at the point of interest at step 422. If this difference does not exceed a threshold at step 424, the current EOT position is again obtained at step 426 and step 422 is repeated. As above, the threshold utilized in step 424 may be zero but preferably includes a safety margin to account for positioning system errors.

If the difference exceeds the threshold at step 424 (signifying that the end of the train has passed the point of interest), the speeds reported by the EOT and HOT positioning systems are compared at step 428. The purpose of this comparison is to ensure that the EOT and HOT are not traveling at significantly different speeds, which would be indicative of a train separation. If the difference in EOT and HOT speeds is greater than a threshold (again, nominally zero but preferably including a safety factor to account for differences in speed caused by slack between cars in

train and positioning system errors) at step 430, then the control module 110 warns the operator of a possible train separation at step 432. If the difference in EOT and HOT speeds is less than the threshold at step 430, then the control module 110 reports (e.g., to the dispatcher 160 via the transceiver 150) that the end of the train
5 has passed the point of interest at step 434.

It should be noted that the comparison of speeds between the HOT and EOT positioning systems 120, 130, while preferable because it adds an additional degree of safety, is not strictly necessary.

Obviously, numerous modifications and variations of the present invention
10 are possible in light of the above teachings. It is therefore to be understood that within the scope of the appended claims, the invention may be practiced otherwise than as specifically described herein.

WHAT IS CLAIMED IS:

1. A method for determining that an end of train has passed a point comprising the steps of:

5 determining that a head of a train has reached a first position at a point of interest;

detecting, after the determining step, that the head of the train has traveled a distance past the first position, the distance being at least as long as a length of the train;

10 obtaining a second position of an end of the train after the detecting step; comparing the first position to the second position to verify that the end of the train has passed the point of interest.

2. The method of Claim 1, wherein the comparing step is performed by calculating a difference between the first position and the second position and comparing the difference to a threshold.

15 3. The method of Claim 2, wherein the threshold is zero.

4. The method of Claim 2, wherein the threshold includes a safety factor.

5. The method of Claim 1, wherein the step of determining that the head of train has traveled the distance is performed by integrating successive differences in position of the head of the train.

20 6. The method of Claim 5, wherein the integrating step is performed at a periodic rate.

7. The method of Claim 6, wherein the periodic rate is approximately once every second.

8. The method of Claim 1, wherein the step of determining that the head of train has traveled the distance is performed by determining a third position of the head of the train at a time after the head of the train is at the first position and calculating a difference between the third position and the first position.

5 9. The method of Claim 1, further comprising the step of accepting a length of the train from a dispatcher.

10 10. The method of Claim 1, further comprising the step of accepting a length of the train from an operator.

10 11. The method of Claim 1, further comprising the step of determining a length of the train based at least in part on a position reported by a positioning system located at an end of the train and a position reported by a positioning system located at a head of the train.

15 12. The method of Claim 1, wherein the first position is obtained from a first positioning system located at the head of the train and the second position is obtained from a second positioning system located at an end of the train

13. The method of Claim 11, wherein the positioning system located at the end of the train is a Global Positioning System (GPS) receiver and the positioning system located at the head of the train is a GPS receiver.

20 14. The method of Claim 12, further comprising the step of comparing a speed reported by the first positioning system to a speed reported by the second positioning system to detect a separation of the head of the train from the end of the train.

15. A method for determining that an end of train has passed a point comprising the steps of:

determining that a head of a train has reached a first position at a point of interest;

5 detecting, after the determining step, that an end of the train has traveled a distance at least as long as a length of the train;

obtaining a second position of the end of the train after the detecting step;

comparing the first position to the second position to verify that the end of the train has passed the point of interest.

10 16. The method of Claim 15, wherein the comparing step is performed by calculating a difference between the first position and the second position and comparing the difference to a threshold.

17. The method of Claim 16, wherein the threshold is zero.

15 18. The method of Claim 16, wherein the threshold includes a safety factor.

19. The method of Claim 15, wherein the detecting step is performed by integrating successive differences in position of the end of the train.

20. The method of Claim 19, wherein the integrating step is performed at a periodic rate.

20 21. The method of Claim 20, wherein the periodic rate is approximately once every second.

22. The method of Claim 15, further comprising the step of accepting the length of the train from a dispatcher.

23. The method of Claim 15, further comprising the step of determining the length of a train based at least in part on a position reported by a positioning system located at an end of the train and a position reported by a positioning system located at a head of the train.

5 24. The method of Claim 15, wherein the first position is obtained from a first positioning system located at the head of the train and the second position is obtained from a second positioning system located at an end of the train.

25. The method of Claim 24, further comprising the step of comparing a speed reported by the first positioning system to a speed reported by the second
10 positioning system to detect a separation of the head of the train from the end of the train.

26. A system for determining that an end of train has passed a point, the system comprising:

a control unit;

15 a first positioning system in communication with the control unit, the first positioning system being located at a head of a train;

a second positioning system in communication with the control unit, the second positioning system being located at an end of the train;

the control unit being configured to perform the steps of

20 determining when a head of a train has reached a first position at a point of interest using information from the first positioning system;

detecting when the head of the train has traveled a distance past the first position, the distance being at least as long as a length of the train;

obtaining a second position of an end of the train from the second positioning system when the head of train has traveled the distance;

comparing the first position to the second position to verify that the end of the train has passed the point of interest.

5 27. The system of Claim 26, wherein the comparing step is performed by calculating a difference between the first position and the second position and comparing the difference to a threshold.

28. The system of Claim 27, wherein the threshold is zero.

29. The system of Claim 27, wherein the threshold includes a safety factor.

10 30. The system of Claim 26, wherein the step of determining that the head of train has traveled the distance is performed by integrating successive differences in position of the head of the train.

31. The system of Claim 30, wherein the integrating step is performed at a periodic rate.

15 32. The system of Claim 31, wherein the periodic rate is approximately once every second.

33. The system of Claim 26, wherein the step of determining that the head of train has traveled the distance is performed by determining a third position of the head of the train at a time after the head of the train is at the first position and
20 calculating a difference between the third position and the first position.

34. The system of Claim 26, further comprising the step of accepting the length of the train from a dispatcher.

35. The system of Claim 26, further comprising the step of determining a length of a train based at least in part on a position reported by the first positioning system and a position reported by the second positioning system.

5 36. The system of Claim 26, wherein the first and second positioning systems are GPS receivers.

37. The system of Claim 26, wherein the control unit is further configured to perform the step of comparing a speed reported by the first positioning system to a speed reported by the second positioning system to detect a separation of the head of the train from the end of the train.

10 38. The system of Claim 26, further comprising a storage device connected to the control unit, the control unit further being configured to obtain the point of interest from the track database.

39. A system for determining that an end of train has passed a point, the system comprising:

15 a control unit;

a first positioning system in communication with the control unit, the first positioning system being located at a head of a train;

a second positioning system in communication with the control unit, the second positioning system being located at an end of the train;

20 the control unit being configured to perform the steps of

determining a first position of a head of a train at a point of interest;

detecting, after the determining step, when an end of the train has traveled a distance at least as long as a length of the train;

obtaining a second position of the end of the train after the detecting step;

comparing the first position to the second position to verify that the end of the train has passed the point of interest.

5 40. The system of Claim 39, wherein the comparing step is performed by calculating a difference between the first position and the second position and comparing the difference to a threshold.

41. The system of Claim 40, wherein the threshold is zero.

42. The system of Claim 40, wherein the threshold includes a safety factor.

10 43. The system of Claim 39, wherein the detecting step is performed by integrating successive differences in position of the end of the train.

44. The system of Claim 43, wherein the integrating step is performed at a periodic rate.

15 45. The system of Claim 44, wherein the periodic rate is approximately once every second.

46. The system of Claim 39, wherein the control unit is further configured to perform the step of accepting the length of a train from a dispatcher.

20 47. The system of Claim 39, wherein the control unit is further configured to perform the step of determining the length of the train based at least in part on a position reported by the first positioning system and a position reported by the second positioning system.

49. The system of Claim 39, further comprising the step of comparing a speed reported by the first positioning system to a speed reported by the second

positioning system to detect a separation of the head of the train from the end of the train.

50. The system of Claim 39, further comprising a storage device connected to the control unit, the control unit further being configured to obtain the point of interest from the track database.

ABSTRACT

A controller determines that an end of train (EOT) has passed a point through the use of positioning systems at the head of the train (HOT) and the EOT. In a first method, the controller obtains the HOT position at a point of interest from the HOT positioning system. The controller then determines when the train has traveled a distance equal to the length of the train and then interrogates the EOT positioning system. If the difference between this position and the position reported by the HOT positioning system at the point of interest exceeds a threshold, then the EOT has passed the point. In a second method, when the HOT positioning system reaches a point of interest, the position reported by the EOT positioning system is integrated until the total distance traveled by the EOT equals the length of the train.

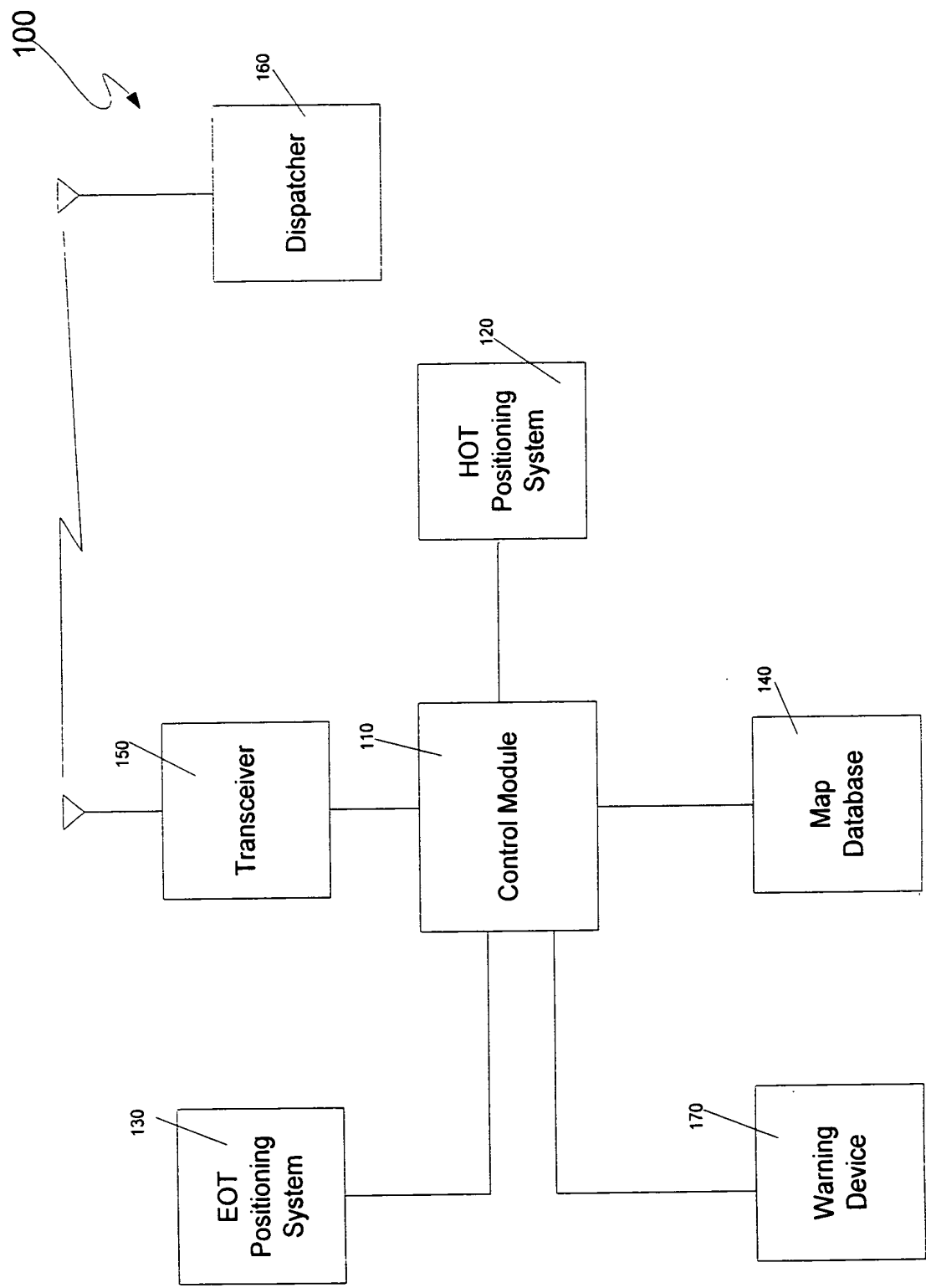


Figure 1

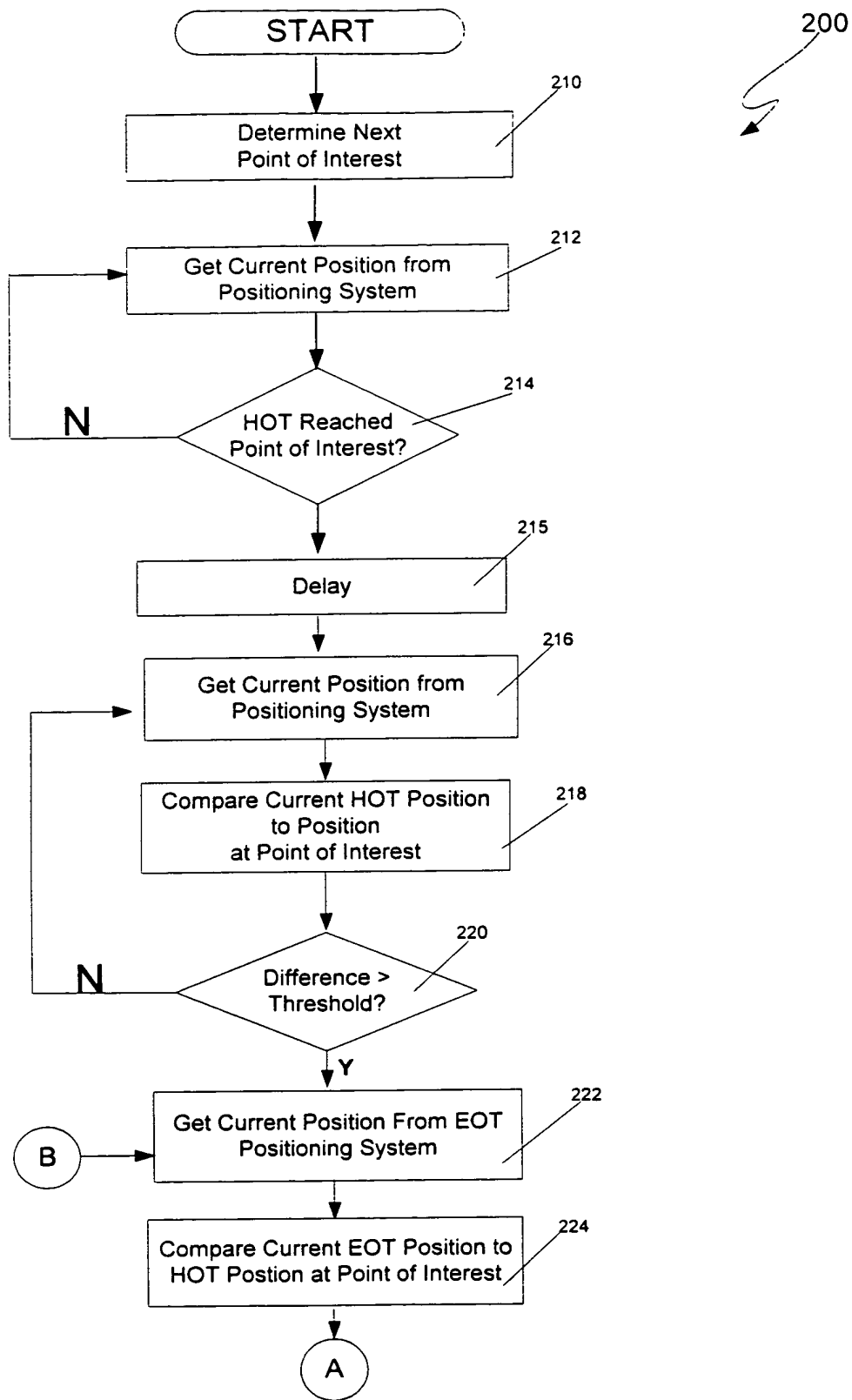


Figure 2a

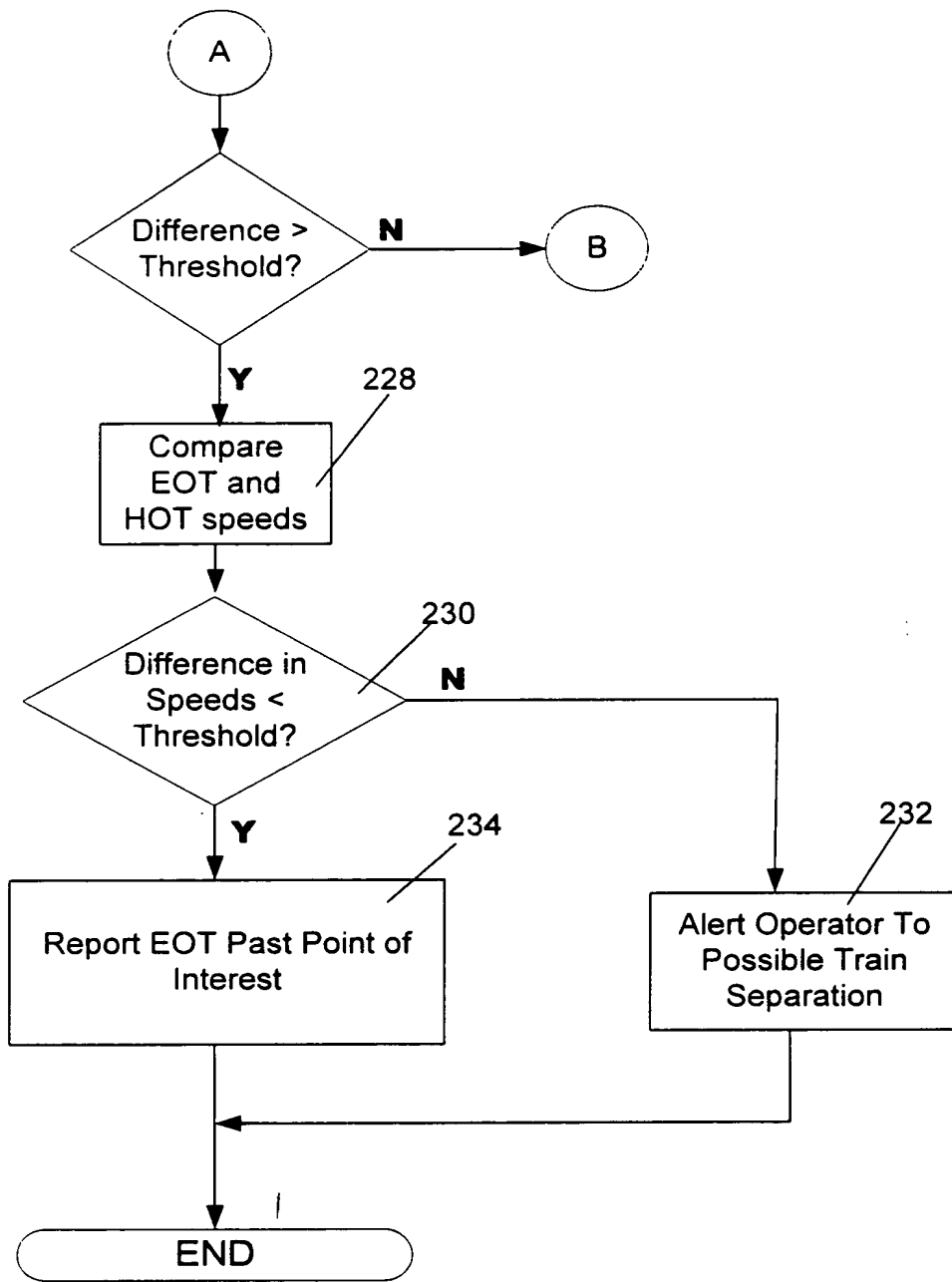
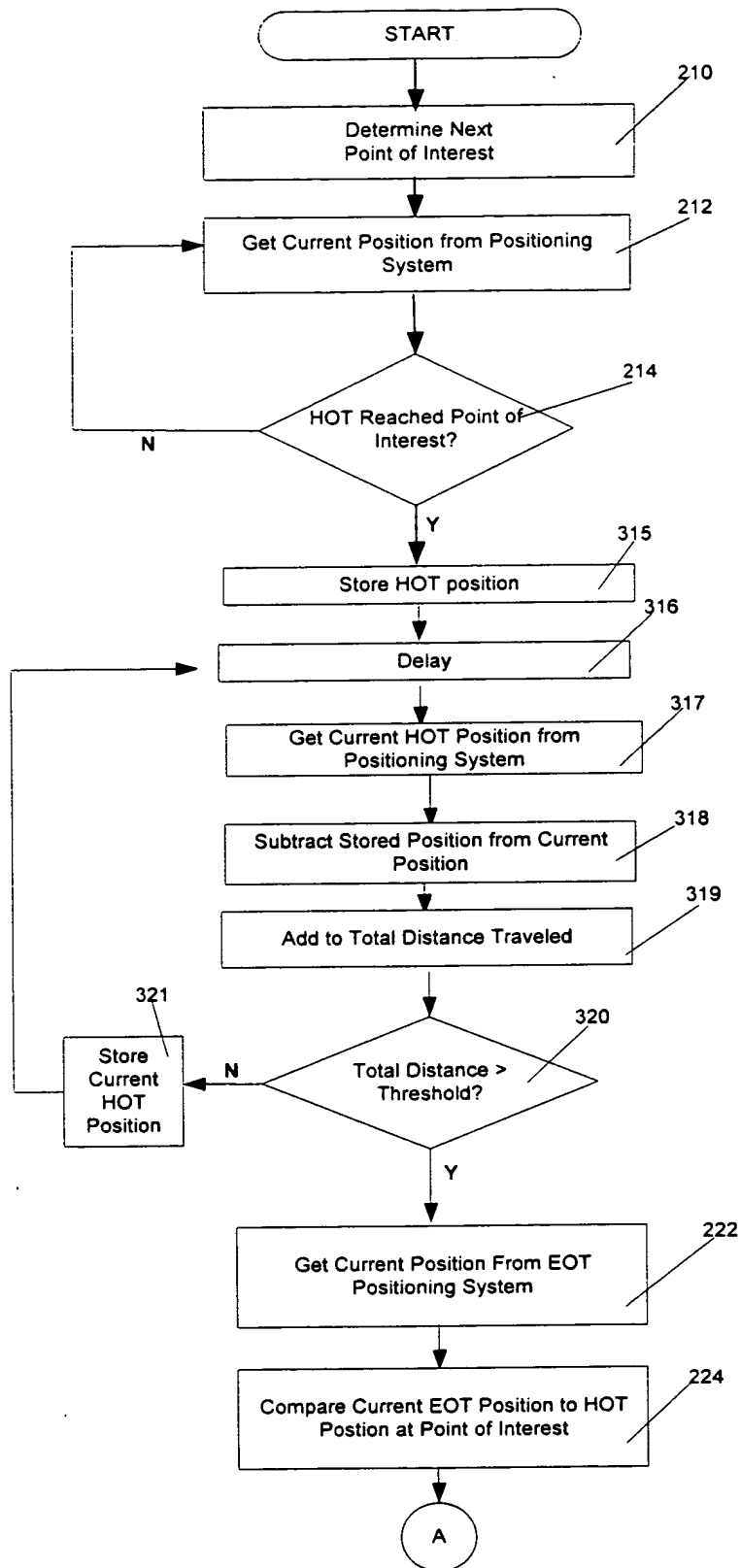


Figure 2b



(in Fig. 2)

Figure 3

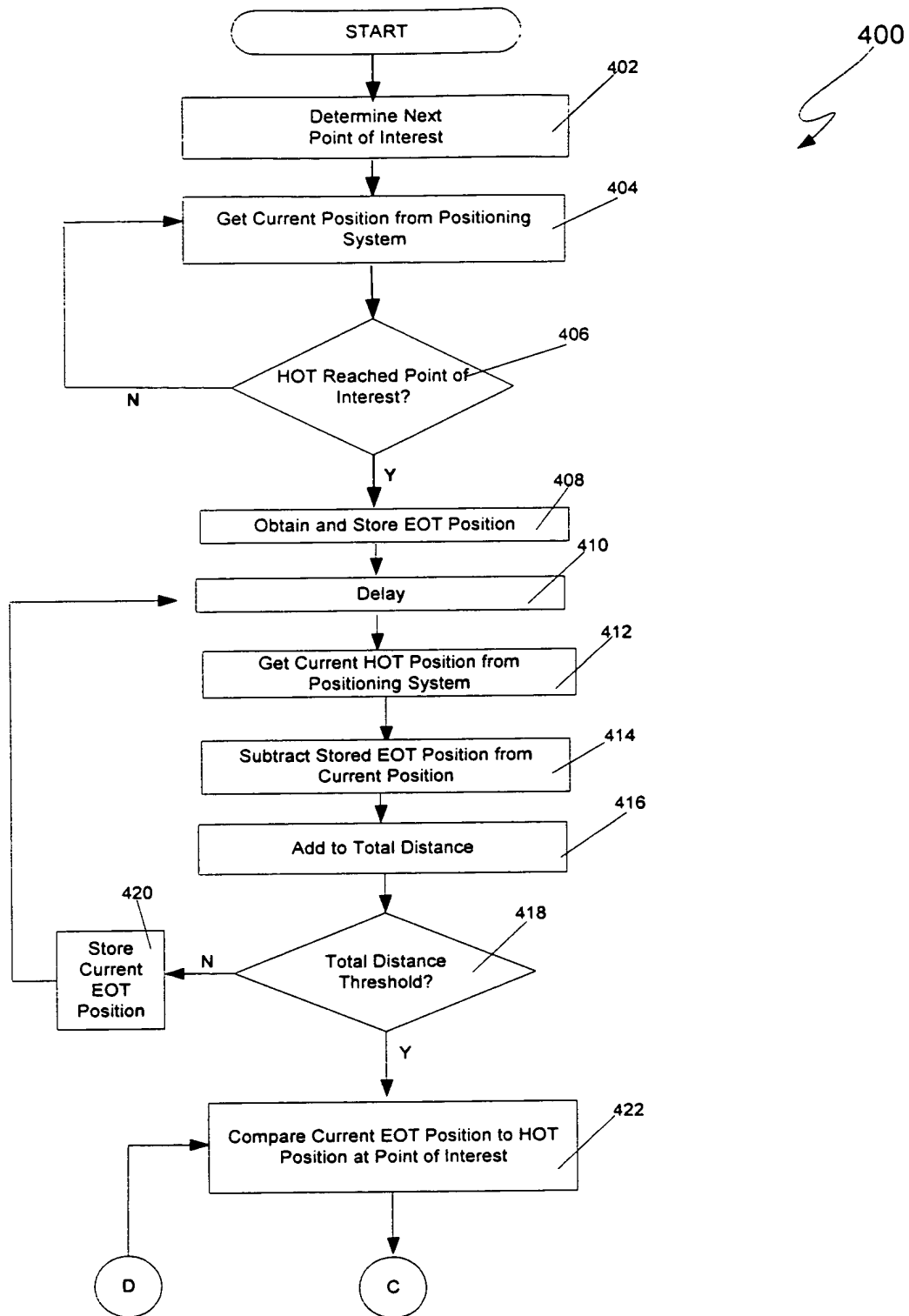


Figure 4a

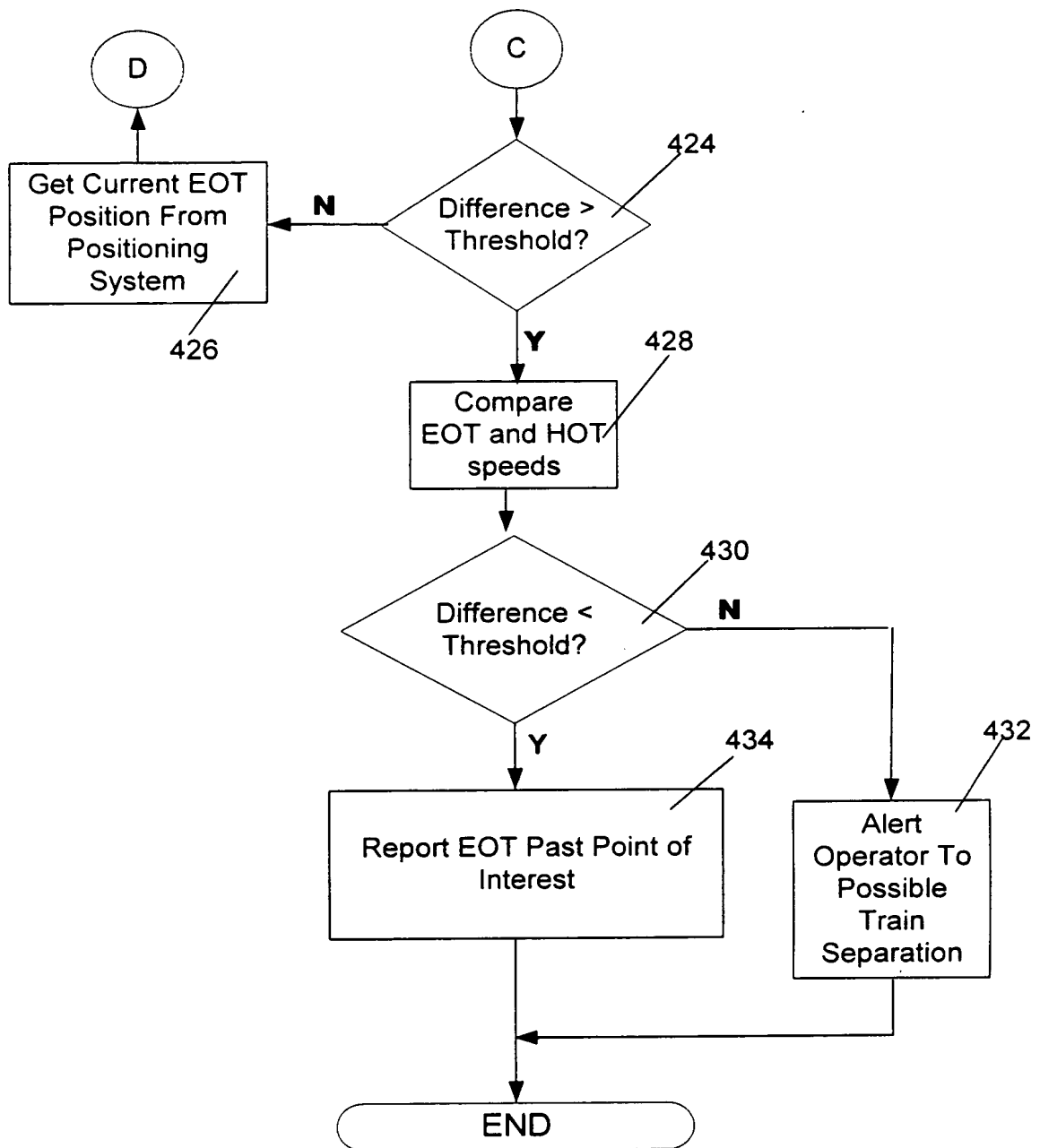


Figure 4b